OBITUARY NOTICES

OF

FELLOWS DECEASED.

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JOHANNES WISLICENUS. 1835—1902.

There are few branches of science so indelibly associated with the second half of the last century as that highly-specialised study of the compounds of carbon, which is commonly called organic chemistry. The marvellously rapid development of this branch of chemistry will ever remain one of the greatest monuments to the enthusiasm and industry of scientific workers. Amongst the master-builders of this imposing edifice, one of the most conspicuous was Johannes Wislicenus, who, over a period of more than forty years, devoted his great natural gifts and extraordinary energy to this work of construction.

Although in 1853, at the early age of 18, we already find Wislicenus acting as assistant to Heintz, then Professor of Chemistry in the University of Halle, his further progress to academic distinction did not proceed on the stereotyped lines usually followed by those who succeed in gaining access to the select professorial caste of the German universities. Wislicenus' early life is, in fact, of special interest, taking us back as it does to a time when liberty and freedom of speech were ideals for which serious sacrifices had to be made even in the countries of Western Europe.

J. Wislicenus

(about 1875).

Wislicenus was born on June 24, 1835, at Kleineichstad in Saxony, of which village his father, Gustav Adolf Wislicenus, was the pastor. He came of one of those stocks which betray their independent spirit and originality by finding themselves out of sympathy with the established religion of their fellow-countrymen, for the Wislicenus family, originally Polish, had, in consequence of their Protestant zeal, been forced to fly from Poland into Hungary, from where, in the 17th century, they passed into Germany. For several generations members of the family were engaged in the ministry at

Schönburg, near Naumburg. The inherited capacity of suffering for conscience sake, however, was again manifested in Wislicenus' father, who, in consequence of belonging to a students' society ("Burschenschaft") for the promotion of liberal principles, was, in 1824, condemned to twelve years' imprisonment in a fortress, but was pardoned after suffering confinement for five years. Far from being crushed by this cruel punishment, he was again in 1844 identified with resistance to the persecution carried on by the orthodox party under William IV of Prussia, and for his liberal preaching he was in 1846 deprived of his living as pastor in Halle. He at once founded a free church in the same city, but was in 1853 condemned to two years' imprisonment for publishing a work entitled "The Bible in the Light of the Culture of our Time," to escape which he was obliged to fly to America. It would, indeed, be difficult to find a more ideal ancestry for a man of science!—a line of forefathers in whom two hundred years of exile and persecution had been unable to extinguish the innate love of truth and heroic devotion to the cause of free thought.

Through his father's flight to America, Johannes Wislicenus' studies at the University of Halle had to be interrupted at the age of 18, for it was under his guidance that the family followed the father to the New World. Owing to limited resources they were obliged to set out across the Atlantic in a sailing ship, on which they embarked in England, but hardly had they got under way before cholera broke out on board, and the disease spread with such rapidity that the state of affairs soon became most serious. The writer well remembers the graphic description given him by Wislicenus of the scenes which ensued. The doctor, a Scotchman, proved himself wholly incapable of grappling with the situation; he entirely neglected the steerage passengers, and had recourse to the whisky bottle. Young Wislicenus thereupon undertook not only the treatment but even the nursing of the wretched patients who had been left to their fate by the medical officer. The pestilence, however, assumed such dimensions that the ship was turned back to England, and the voyage abandoned. Owing to the family being provided with money but barely sufficient to carry them to America, the enforced delay in England entailed on them much hardship and suffering, and the bitter experiences of this dark time must have so impressed themselves on the youthful Wislicenus that it was not until thirty-four years later that he could be induced to revisit this country, notwithstanding the reiterated invitations of his many English friends.

On ultimately reaching the United States it was again to Wislicenus, but little more than a boy in years, that the family looked for material support. He became assistant to Professor Horsford, of Harvard, and subsequently carried on practice as an analytical chemist in New York. Wislicenus used to relate many interesting episodes of his three years' life in the States. On one occasion, as he told the writer, he was visited in his laboratory by two Americans, who requested him to analyse and report on a sample of water from a mineral spring which they wished to push for its therapeutic properties. They said they must have the analysis and report by the afternoon of the same day. This, said Wislicenus, was quite impossible, as the analysis would certainly take several days, and possibly longer. His visitors replied that they would, of course, be prepared to pay him more than the usual fee, but that the results of analysis must be in their hands by the afternoon. Their surprise was unbounded when Wislicenus declined to oblige them, and, saying that they guessed he must be a young greenhorn, they went to another chemist of high repute in the city, who duly furnished them with an elaborate analysis and report in the course of a few hours. This chemist subsequently informed Wislicenus, quite cynically, that, to meet the exigencies of the case, he had devised a method of analysing water by smell! In such an atmosphere Wislicenus began to feel doubts as to his moral security, and he formed the resolve of returning to Europe as soon as he possibly could.

In 1856 the family recrossed the Atlantic and settled in Zürich, where Wislicenus resumed his studies, and in the following year became private assistant to his former master, Professor Heintz, at Halle. Here he remained until 1859, taking his Ph.D. degree in 1858 on an investigation which he had made of the basic decomposition products obtained by heating aldehyde-ammonia. This, and several other pieces of work, were published in conjunction with Heintz, whilst Wislicenus' first independent papers appeared in 1859 and treated of the theory of "mixed types," with special reference to the derivatives of glycerine and glycol.

The next step in Wislicenus' career should normally have been his "habilitation as Privatdocent" at the University of Halle, but his participation in liberal movements, both political and religious, barred the way, and he was informed that unless he left public politics entirely alone he would not be permitted to place his foot on this next rung of the academic ladder. Wislicenus was, however, not the man to be coerced by such methods, and, preferring freedom in a foreign country to bondage in his own, he migrated to Zürich, and became Privatdocent at the University there.

There is probably no city in Europe which has such a broadening influence on the human sympathies as Zürich; its atmosphere is unique. The intellectual centre of the Swiss Republic, it has become the asylum of many distinguished refugees and malcontents from the despotic states of the Continent, whilst its geographical position leads to its being traversed by a continuous stream of visitors of all nationalities throughout the year. In this international colony of free thought and uncompromising originality, and placed amidst the purest of democracies, there is no soil for the growth of those privileges attaching to birth and wealth with which so many other states are honeycombed. In Zürich you will not see "Liberté, Egalité, Fraternité," inscribed on the public buildings and posted up at the street-corners, but you will see these principles actually practised, and the man who is unwilling to conform to their spirit will find this city a very undesirable dwelling place.

The thirteen years (1859 to 1872) which Wislicenus spent amongst these surroundings were in many respects the most important of his life, and the experience he gained during this time must have largely contributed to the building up of that rare personality which always made him such a marked figure amongst his academic colleagues.

Wislicenus' career in Zürich was an extraordinarily rapid and brilliant one, more and more responsible posts in quick succession being entrusted to him by the Swiss Government. In 1861 he was made Professor of Chemistry and Mineralogy in the Cantonal School, in 1864 Extraordinary Professor, and in 1867 Ordinary Professor at the University, whilst in 1870 the still higher office of Professor at the Polytechnikum was conferred on him, and of this famous institution he became, in the following year, Director. It was in Zürich that Wislicenus carried out some of his most memorable researches, and began to display his great power of correlating isolated facts in support of wide generalisations. Thus in 1862 he published important papers referring to the constitution of the lactic acids, and supported his views by the experimental synthesis both of ethylene and ethylidene lactic acid. Then followed a long series of investigations on oxyacids, which had a most important influence on the development of structural organic chemistry, and ultimately led to a complete elucidation of the remarkable phenomena of isomerism exhibited by the lactic acids. Thus, when Wislicenus had proved that there were three isomeric lactic acids, whilst structural formulæ predicted only the existence of two, he did not hesitate to hazard the opinion before the "Naturforscher Versammlung" at Innsbruck in 1869, that this isomerism would be explicable by a consideration of the grouping of the atoms in space and by the use of solid model formulæ. In his own words—

"*Derlei feinere Isomerieen würden sich wohl durch räumliche Vorstellung über die Gruppirung der Atome, also durch Modellformeln deuten lassen.*" (Berichte d. deutschen chem. Gesellschaft, 1869, pp. 550 and 620.)

This pregnant suggestion was a few years later developed by Le Bel and Van't Hoff into an entirely new domain, now known as *Stereochemistry*, with most important and far-reaching consequences. This branch of chemistry has attracted an ever-increasing number of workers, by whose labours a vast amount of experimental material has been accumulated, the subject being one of surpassing interest, largely owing to its intimate connection with the chemistry of vital processes. To this field of enquiry Wislicenus himself again returned about twenty years later, and made some most important contributions both theoretical and practical, which are summarised in his classical memoir, "Ueber die räumliche Anordnung der Atome in organischen Molekülen und ihre Bestimmung in geometrisch-isomeren ungesättigten Verbindungen," published before the Köngl. sächsische Gesellsch. der Wissenschaften in 1887. A most eloquent discourse on this subject was delivered by Wislicenus before Section B of the British Association in the same year, and formed one of the most memorable features of the Manchester Meeting.

During the Zürich period of his career, Wislicenus carried out, in conjunction with his friend Adolf Fick, then Professor of Physiology at the same University, what must be regarded as one of the most important and fundamental physiological experiments ever made, revolutionising as it did the doctrine introduced by Liebig, that albuminoids were the exclusive source of muscular power, and that the energy contained in the fats and carbohydrates was only employed in maintaining the temperature of the body. By climbing the Faulhorn (Bernese Oberland), on August 30, 1865, taking food only from which albuminoids were carefully excluded, and also determining the total nitrogen excreted during the climb, Fick and Wislicenus conclusively proved that the muscular energy was principally derived from the oxidation of fats and carbo-hydrates. In fact the energy liberated in the oxidation of albuminoids (as measured by excreted nitrogen) did not amount to one-third of that required to perform even that minimum of work involved in raising the body through the vertical height of the mountain. This classical experiment was shortly afterwards supplemented by the late Sir Edward Frankland's determinations of the heat of combustion of muscular fibre, and of numerous nitrogenous and non-nitrogenous food-stuffs, which threw quite new light on the total possible energetic values of these materials. (See Frankland's 'Experimental Researches,' London, 1877, pp. 918–959.)

Wislicenus having thus, by the fertility of his labours on foreign soil, won his way into the front rank of living chemists, it was not surprising that in 1872 he should have been called to Germany to occupy the Chair, rendered vacant in the University of Würzburg by the death of the celebrated Adolf Strecker. The filling of chairs by those who have distinguished themselves as university teachers in foreign lands has been of not unfrequent occurrence in Germany, and has proved a great source of academic strength to the country.

The thirteen years (1872 to 1885) which Wislicenus spent in Würzburg, were those during which his rare gifts were probably displayed to the greatest advantage. They were the thirty-seventh to the fiftieth years of his life. This period was principally occupied in a long series of investigations bearing on the constitution, reactions, and synthetic uses of that marvellous substance, *acetoacetic ester*, which had been independently discovered by Geuther, and by Frankland and Duppa some ten years previously. It would be difficult to say how many publications concerning this classical body emanated from the Würzburg laboratory during the Wislicenus *régime*, whilst still more difficult would it be to enumerate his pupils who were enabled to append the magic letters, "Ph.D.," to their names as the outcome of investigations which they had made on this fertile compound of carbon. These researches led not only to the elucidation of the constitution and reactions of acetoacetic ester itself, but to important further advances, such as the uses of malonic ester by Conrad, Bischoff, and Guthzeit, the synthesis of succinyl-succinic ester by F. Herrmann, the production of polymethylene rings by W. H. Perkin, junior, and the synthetic formation of the pyridine ring by Hantzsch. All these achievements must be regarded as the direct result of the *Zeitgeist* prevailing in the laboratory, and of the inspiration derived from the master.

Of other investigations which emanated from the Würzburg laboratory during Wislicenus' tenure of office, mention may be made of the synthesis of hydantoic acid from cyanic acid and glycocoll, the synthesis of ethylmalonic acid by the action of potassium cyanide on the α-bromo derivative of normal butyric acid, researches on benzoïn, on biuret derivatives, on the constitution of phosphorous acid, on the production of guanidines by the interaction of mercuriphenylammonium chloride on thiocarbamides, and studies on the isomeric crotonic acids. During the later years also a number of his pupils were engaged in researches on the aromatic and camphor compounds. From this brief survey it will be sufficiently apparent that the investigations in his laboratory were spread over an unusually wide field of organic chemistry.*

Although during the Würzburg period Wislicenus was not actually engaged on any work relating to stereochemistry, the magnetic eloquence of his discourses on this fascinating domain doubtless led several of his Würzburg pupils—Hantzsch, Bischoff, Purdie, and others—to subsequently devote their best energies to extending its boundaries in various directions.

The remarkable strength of the University of Würzburg at this time, in the Faculties of Science and Medicine, may be gathered from the fact that Wislicenus numbered amongst his colleagues such men as Adolf Fick (physiology), v. Kölliker (anatomy), v. Bergmann (surgery), v. Gerhardt (medicine), Kohlrausch (physics), and Sachs (botany).

On the death of Kolbe, in 1885, Wislicenus was called to the Chair of Chemistry in the University of Leipzig, where the duty devolved on him of directing the energies of an even larger school of chemistry than at Würzburg. The demands made upon a professor of chemistry in one of the large universities of Germany can only be realised by those who have studied there, as they have no parallel in the present academic system of our own or any other country. The duties can only be properly performed by a man who combines commanding ability, extraordinary capacity for work, and iron physique.

This period of Wislicenus' career, which only closed with his death in 1902 (December 5), was distinguished by many researches of great importance, more especially those relating to the configuration of unsaturated organic molecules (fumaric and maleïc acids, the crotonic acids, angelic and tiglic acids, the stilbenes, etc.), and to the synthesis of cyclic compounds (reduction of diketones to cyclic pinacones).

In respect of its influence on the progress of organic chemistry, Wislicenus' work falls into three parts, which are broadly coincident with his academic activity in Zürich, Würzburg, and Leipzig respectively. His work in each of these centres was destined to produce a far-reaching effect. The investigations on the lactic acids, carried out in Zürich, were, as already pointed out, largely responsible for the fertile speculations of Van't Hoff, and may thus be regarded as the foundation stones of structural stereochemistry. In his work at Würzburg on acetoacetic ester, the extraordinary value of this substance as a synthetic agent was displayed in a great variety of ways, and led not only to its extended use, but also indirectly to the discovery of numerous other agents of a similar character, and thus to a great multiplication of the methods available for building up carbon compounds. Lastly, by the speculative and experimental work in the domain of stereochemistry, which distinguished his tenure of the Chair at Leipzig, he provided the widest and most consistent explanation yet given of the phenomena of isomerism manifested by numerous unsaturated carbon compounds. It will be evident, therefore, that Wislicenus' influence is discernible far and wide in that extraordinarily rapid development of organic chemistry which took place in the latter half of the century that is just past.

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* For a complete list of Wislicenus' publications, see 'Berliner Berichte,' vol. 37 (1905), pp. 4928—4946, these eighteen pages being covered by the enumeration of their titles, joint authors' names, and references alone.

That the great merit of Wislicenus' work was recognised by the world during his lifetime is attested by the public honours which poured in upon him. In this connection it will be sufficient to mention that he received high orders from the rulers of Bavaria, Saxony, and Norway, two of which carried with them the patent of nobility. It was, however, characteristic of the man that he consistently declined to make use of the titles which Courts had thrust upon him. He was elected a Foreign Member of the Chemical Society in 1888, and a Foreign Member of the Royal Society in 1897, receiving the Davy Medal in the following year.

Of much greater value to Wislicenus than the prizes of scientific societies and the favours of princes was the knowledge of the feelings of love and respect entertained for him by his pupils, and indeed by all who came into personal relations with him. Certainly it would be difficult to conceive of anyone more liberally endowed by nature with precisely those qualities which are calculated to win the hearts of men. The majestic form and classical features might have well served Phidias or Praxiteles as a model for the Olympian Zeus. His mellow voice and wonderful command of language, guided by artistic intuition and the purity of his spirit, led him to be acknowledged as one of the most magnetic and inspiring orators of Germany. His lofty idealism and unswerving devotion to duty he carried into every phase of life, and his aspirations he had the power of communicating to those with whom he came into contact. Without any touch of Puritanism in the ordinary sense of the word, for he was full of good-fellowship and the friend of conviviality, he was one of those men who purify all their surroundings. In Wislicenus' presence it was almost impossible for anyone to harbour a mean or unworthy thought, his searching though optimistic gaze irresistibly drawing forth the good and banishing the evil.

A man who thus combined such high qualities of heart and mind with a living enthusiasm for his science, could not fail to be a stimulating teacher. He gave the most conscientious attention to all students, from the beginner upwards, and sought in his daily visitation of the laboratories to awaken interest and sharpen the powers of observation and reasoning in his pupils, rejoicing with those that were successful in their investigations and encouraging to renewed effort those whom some failure had depressed. It was by means of this contagious enthusiasm and warm sympathy of the master that the great hives of industry at Würzburg and Leipzig were kept humming, and not by any visible disciplinary measures which are the resort of those who, although placed in authority, were never born to rule.

It was inevitable that one so full of human sympathy and with so much instinct for practical affairs as Wislicenus, should have been deeply interested in the momentous political changes through which Germany passed during his lifetime. The key to the political sentiments of his later life is to be found in the circumstance that he was at the still impressionable age of thirty-five in those stirring times when a united Germany was forged out of incoherent fragments by the determined men who brought to such a successful issue the great struggle of 1870. This united Germany, which had been the dream of the liberal idealists of the previous generation, was rendered an accomplished fact by a man, who, trusting in material strength alone, had no sympathy with liberal aspirations. Nevertheless, the great work actually accomplished by Bismarck and his iron associates in the drama of 1870, secured the unbounded admiration of Wislicenus, as it did also of so many other Germans who were both by nature and by tradition imbued with liberal principles. Such men felt that the ideal but abortive aspirations of 1848 must be sunk for the time at least, and that their immediate energies should be directed to the consolidation and expansion of the great empire which had been built upon the throne of the Hohenzollerns as a base. Thus in the latter half of his life we find Wislicenus an enthusiastic admirer of the Iron Chancellor, of the Emperor William, and of the military system; he was one of the founders of the "Alldeutscher Verband," and was amongst the first to urge upon his countrymen the necessity for increasing the strength of the German navy. In giving his unqualified support to these men and to these measures, it is evident that Wislicenus must have been drawn into that chauvinistic vortex which now for a generation has hung over the civilised world—like a great storm-cloud of ever-increasing density, but in which at length a small rift is beginning to appear in the shape of the newer idealism of those who dream not of empire but of the universal brotherhood of man. Could another decade have been added to the life and activity of Wislicenus, there can be little doubt that his powers of advocacy would have been enlisted in promoting that great work, which has already begun, of restricting the use, if not of limiting the power, of the sword on the earth.

Any account of Wislicenus would be wholly incomplete without a reference to his family life, the circumstances of which are responsible for the manifestation of some of his greatest qualities. Soon after settling in Zürich, he married Katharine Sattler, who belonged to a Bavarian family remarkable for talent and originality, and who herself was possessed of great gifts as an artist. Her grandfather was with Russ, the inventor, in 1814, of the well-known pigment, *Schweinfurt-Green.* Wislicenus' domestic happiness was, however, destined to be of only short duration. In 1866 his brother Hugo, Privatdocent of German Archæology in Zürich, was killed in a mountaineering disaster on the Tödi, and a few years later his wife, to whom he was most devotedly attached, developed an incurable mental disorder, from which she suffered for upwards of thirty years. She died in 1904, and thus survived her husband by more than a year.

Wislicenus had four sons and two daughters, to all of whom he was attached with something more than fatherly affection, the bond of union being strengthened by the crushing sorrow resting upon the otherwise high-spirited and joyous children, over whom he watched with a mother's solicitude. Of the four sons, two were taken from him—Conrad in the first bloom of youth, and Alwin, who displayed extraordinary talent as a painter, under most painful circumstances in early manhood. Of the remaining two sons, the elder, Professor Wilhelm Wislicenus, was called to the Chair of Chemistry at Tübingen shortly before his father's death; whilst the younger, Professor Hans Wislicenus, had already some years previously been appointed to the Chair of Chemistry at the Agricultural Academy in Tharandt, Saxony. Of the daughters, the elder, Emilie, devoted herself absolutely to the father whom she loved so well, and for whose companionship she renounced, without murmur or hesitation, the artist's career for which she was so highly qualified. The second daughter, Marie, likewise endowed with artistic talents, married Dr. Adolf Fick, the well-known ophthalmologist, and it was her home in Zürich, as well as the homes of his two sons, which became for Wislicenus in his later years the holiday retreats in which the cares and sorrows of a lifetime could be forgotten for a few weeks amidst the radiant faces and the innocent prattle of grandchildren.

That Wislicenus' powerful physique was beginning to decline became apparent several years before his death, but he continued his lectures and attended to his other university duties until July, 1902. In the following vacation he sought relief at Wildbad from the rheumatic pains with which he had long been troubled, but the treatment did not lead to the beneficial results hoped for. He reluctantly yielded to the injunctions of his medical advisers and deputed his work for the whole of the ensuing winter session. The mischief had, however, already proceeded too far for remedy, and on December 5, 1902, he succumbed to a stroke of cerebral apoplexy in the sixty-eighth year of his life.

In Wislicenus the scientific world lost one of the most distinguished chemists of the 19th century, Germany a great orator and patriot, his friends and relatives a strong head and the warmest of hearts, ever ready with counsel or sympathy, and a pillar of strength in the hour of need or tribulation. Lastly, his numerous pupils lament the loss of the master who not only fired them with enthusiasm for their science, but who also, by his great example of unswerving devotion to duty and of resolute fortitude in bearing adversity, inspired them to lead a higher and a nobler life.

P. F. F.

GEORGE JOHNSTON ALLMAN. 1824—1904.

George J. Allman, born in Dublin on September 28, 1824, was a younger son of William Allman, M.D., who was Professor of Botany in the University of Dublin from 1809 to 1844. Dr. William Allman was one of the most distinguished botanists of his time, and was the first professor in the British Isles to introduce (in 1812), and lecture on, the Natural System of Linnæus.

George J. Allman entered Trinity College, Dublin, at an early age, and during his undergraduate course uniformly obtained high honours in Mathematics, pure and applied. He graduated in 1884 as a Senior Moderator and Gold Medalist in those subjects, along with the late Professor Samuel Haughton, F.R.S., who obtained the First Senior Moderatorship of that year. In 1853 he married Louisa, daughter of Mr. John S. Taylor, of Corballis, Co. Meath, and in the same year was appointed Professor of Mathematics in Queen's College, Galway; there he had among his colleagues Sir Thomas W. Moffett, late President of the College, George Johnstone Stoney, F.R.S., John E. Cairnes, the distinguished Political Economist, D'Arcy Thompson, and other men of celebrity. He was made a Member of the Senate of the Queen's University in 1877, and was nominated by the Crown, in 1880, one of the first Senators of the Royal University of Ireland, a position which he filled until the end of his life.

The degree of Doctor of Science (*honoris causa*) was conferred on him in 1882, and he was elected F.R.S. in 1884. He was sent by the Council of his College as a delegate to the University of Bologna on the occasion of the celebration of its Octo-centenary in 1888.

The work by which Dr. Allman's name will long be known is his "History of Greek Geometry from Thales to Euclid," which first appeared in the form of successive articles in various numbers of the Trinity College periodical, entitled 'Hermathena,' and afterwards (in 1889) was published as a volume in the Dublin University Press Series.

To this work Dr. Allman devoted many years of indefatigable study, learned research, and original thought. In it he traced the rise and progress of the sciences of Geometry and Arithmetic, comprising the labours and discoveries of the three great schools of the period, known respectively as the Ionian, the Pythagorean, and the School of Athens. As remarked by Mr. J. S. Mackay at the end of a critical review in the 'Academy,' June 1, 1889, "Nothing so painstaking, so lucid, and so satisfactory has been written on the history of geometry during the period selected, even in laborious Germany." The work was hailed with high praise by scientific and literary journals at home and on the Continent; it was recognised, as having thrown a large amount of new light on the different steps in the early development of science, by distinguished foreigners, such as Tannery, of Paris; Zeuthen, of Copenhagen; Loria, of Genoa; Hultsch, of Dresden; Günther, of Munich; Cantor, of Leipzig, and other well-known mathematical scholars.

Dr. Allman had earlier published several mathematical memoirs, among which was an account of Professor McCullagh's lectures on the "Attraction of the Ellipsoid," which was reproduced in the collected works of McCullagh, published (1880) in the Dublin University Press Series. At a later period he contributed to the 9th Edition of the 'Encyclopædia Britannica' articles on Thales, Pythagoras, Ptolemy, and other Greek philosophers.

Dr. Allman died of pneumonia in Dublin, on May 9, 1904. In every relation of life he was estimable, and his loss will be long felt by a large circle of college and other deeply attached friends. To the latter he was endeared by his affectionate, frank, and genial disposition; and no person who came in close contact with him could fail to be impressed by the integrity, sincerity, and strong sense of duty which were among his marked characteristics.

B. W.

SIR ISAAC LOWTHIAN BELL. 1816—1904.

THE father of Sir Isaac Lowthian Bell, Mr. Thomas Bell, came to Newcastle in the year 1808. By birth he was a native of Cumberland, and he entered the offices of a Cumbrian firm, Messrs. Losh and Company. As it was in the employment of this firm that, some 30 years later, Sir Lowthian Bell was to take the first step of his business career, a few particulars of the work in which they were engaged may not be considered out of place.

Messrs. Losh and Company had carried on a general merchants' business in Newcastle, but at the time when Thomas Bell joined them they were launching out into other and wider directions. They had just started the Walker Alkali Works, using Le Blanc's process, and were, in addition, manufacturing malleable iron at Walker, obtaining the pig iron in Scotland.

A few years after his arrival in Newcastle, Thomas Bell married a Miss Catherine Lowthian, and in the year 1816 their son, Isaac Lowthian Bell, was born.

His early education may be said to have been very thorough. It began at that famous fount of learning, Dr. Bruce's Academy in Newcastle-on-Tyne. At that time most Newcastle youths of a certain standing seem to have attended Dr. Bruce's school. Many became very distinguished men, and though, in latter day Newcastle, their place knoweth them no more, yet the old school and its master are by no means forgotten. From this place young Bell passed first to Denmark and then to Germany; next to Edinburgh University, and finally to France. He studied in Paris for a time, and then went to Marseilles, where he learned a new process for the manufacture of alkali. On his return from France, being by this time 19 years old, he entered the offices of his father's firm, Messrs. Losh, Wilson, and Bell, in Newcastle. He only remained for about a year in Newcastle, and then was sent to Walker-on-Tyne to manage the firm's rolling mills there. His labours at Walker, and incidentally his connection with Messrs. Losh, Wilson, and Bell, seem to have lasted for about the next eight or ten years. This period may be said to have completed his education, if such an expression be permitted of one who continued to acquire knowledge during the whole of his life. Certainly during this time he was taught, and taught himself, a great deal.

He had the advantage of considerable intercourse with Lord Dundonald in connection with the manufacture of railway wheels, which the firm were making under the latter's patent. Lord Dundonald, so well known to history in other spheres of distinction, was not only a man of alert intellect, but also one of considerable scientific attainments. Probably of all Lowthian Bell's instructors, a Mr. John Vaughan, with whom he first came into contact about the year 1842, was the one to whom he owed most. Mr. Vaughan must have been a very remarkable character. He came from Carlisle to look after the rolling mills at Walker. He was, of course, a professor of rule of thumb, but at the same time one imagines that he knew in his own way practically all that was then known about iron. It is an interesting picture, which we have from the pupil's own lips, of these two at their work. They would sit in the mill and watch the work going on, most of the day and often half the night, the elder man expounding, and the youth absorbing, information, which later on he was to translate into the language of science.

In the meantime Mr. Bell had married Miss Margaret Pattinson, and had removed from Newcastle to a house at Benton. His father-in-law, Mr. Hugh Lee Pattinson, was a Fellow of the Royal Society, and was interested in the Felling Chemical Works. It seems to have been at about this time, or a year or two later, that Mr. Bell severed his connection with Messrs. Losh, Wilson, and Bell.

In the year 1844, with two of his brothers, Thomas and John Bell, he took a lease of Captain Blackett's blast furnaces at Wylam-on-Tyne, a venture which, as it turned out, had the most far-reaching results. It was this combination which, in a few years' time, was to become famous as Messrs. Bell Bros.

Their business started upon a moderate scale. Their iron ore was obtained at first from Hareshaw in Northumberland, and afterwards ironstone was collected on the beach at Whitby. Subsequently they used material from the mines at Skinnergrove in Yorkshire.

There is a curious story in connection with this phase of the firm's existence. It was while the Messrs. Bell were working the mines at Skinnergrove that Mr. Bewick, the geologist, told them that he knew where an ironstone bed, 10 feet thick, existed. He refused to disclose its exact locality, as he said that it was far from any railway, and would ruin them if they tried to work it. As a matter of fact, it was at Skelton in Yorkshire, and subsequently Messrs. Bell Bros. became lessees of it.

About the year 1850 Mr. Lowthian Bell assisted his father-in-law to start the Washington Chemical Works. He was connected with this concern for a number of years; in fact, for nearly twenty he lived at Washington, but in spite of this it does not appear that he took quite the same interest in the Washington business as he did in that of Bell Bros.

He eventually, in 1874, parted with his shares in the Washington Company to his two brothers-in-law, Mr. Newall and Mr. Beaumont.

In so many ways, from about the year 1850, is Mr. Lowthian Bell's history the history of Bell Bros., that it would perhaps be easier to trace—at first at all events—the progress of the firm rather than that of the individual.

At this time, then, the great Cleveland ironstone bed had just been discovered, and, in the year 1852, Messrs. Bell Bros. became lessees of a portion of it on the Normanby estate, which was the property of the Ward-Jackson family. After they had obtained, with no little difficulty, this lease, Bell

Bros. determined to open furnaces in closer proximity to their supply of ironstone. This necessitated a great deal of negotiation and a great deal of arrangement, but ultimately the Clarence Works were started on the north bank of the Tees, at what was afterwards to become the town of Middlesbrough. The exact reason for the choice of this spot is believed to have been on Mr. Ralph Ward-Jackson's account, who was one of the owners of the Normanby estate. Further difficulties arose in connection with the railway transport of the ironstone, but eventually the firm obtained an Act of Parliament for the construction of the Cleveland Railway. This result, however, was not reached without severe fighting, for even after the Parliamentary conflicts, which in themselves were memorable, the opposition was not at an end; but the railway was completed at last, and the ironstone was thus brought direct to the furnaces.

In 1854, three furnaces at the Clarence Works were put into blast. There were only two rival establishments on the Tees at this time, Messrs. Bolckow, Vaughan and Company and Messrs. Cochrane and Company.

For the first few years the company seem to have done extremely well. Prices for pig iron were high, and the business was very ably managed.

In 1858, owing to the growth of the Clarence Works, the Normanby supply of ironstone was found to be insufficient, and in consequence of this the firm obtained a lease of a larger tract of country on the Skelton Castle estate. This, it will be remembered, was the El Dorado mentioned by Mr. Bewick.

But lean years were to follow, and in 1861 we hear of pig iron at 44*s.* instead of 71*s.*, as in 1854. However, Messrs. Bell Bros. managed to carry on their works, owing to the careful manner in which their business had been conducted during the prosperous times.

It was at about this time that the West Hartlepool Harbour and Railway Company, who were deeply interested in several collieries in the county of Durham, found themselves, owing to the general depression in trade, unable to carry on their business. The actual railway and harbour works were sold to the North-Eastern Railway Company, of which Mr. Lowthian Bell was made a director in 1865, and Messrs. Bell Bros. were able to purchase a portion of their colliery property.

Thus, in 1864, they became proprietors of the Page Bank Colliery, and in the same year they sank the Brownie Colliery on a large tract of coal which they leased from the late Lord Boyne.

This does not, by any means, exhaust the list of their colliery properties, but will suffice to show that Messrs. Bell Bros. were expanding very rapidly. And in each step of their progress one traces the careful guiding hand of Mr. Lowthian Bell, for it is impossible not to be impressed by the shrewdness and prudence of the policy of the firm. In fact, throughout Mr. Bell's life, one notices the same far-sightedness in connection with almost everything with which he had to do.

In 1874 the firm of Bell Bros. became a limited liability company, and of its history from this point onward a few words will suffice for the purpose of this memoir. Mr. Lowthian Bell did not in any way lose interest in his works; indeed, so far from this being the case, in the course of the next 20 years he acquired practically the whole of the shares in the company. However, the subsequent development of Bell Bros. is better known than its earlier history, and any worthy account of it would occupy too much space to be here introduced. A word may be permitted, however, with regard to the Clarence Works of the present day. They represent, under favourable conditions of trade, an output of about 1000 tons of iron a day. Their rolling appliances are capable of dealing with some 1500 tons of steel ingots, and the number of men employed is about 5000. *Exegit monumentum* might well be said.

Having dealt, though not by any means fully, with Sir Lowthian Bell's commercial career, his scientific achievements may now be considered.

From almost his earliest years he had a considerable leaning towards chemistry. As we have seen, he devoted much of his time to the scientific side of alkali making. And there can be little doubt that, but for his subsequent researches on iron, which rendered him so famous, and which fully occupied him, his work on this subject would have earned for him the highest consideration as a practical chemist.

But, as has been stated, it was in connection with the metallurgy of iron that his chief work was accomplished. For the last 50 years of his life he had few superiors in general knowledge of the subject, and as far as the blast furnace is concerned he was probably without equal. He it was who first endeavoured to explain the actual conditions which exist inside a blast furnace, and to his investigations was due, to no small extent, the discovery of the Thomas-Gilchrist process.

In 1872 he published that standard work of reference, for all who are interested in the manufacture of pig-iron:—

"Chemical Phenomena of Iron Smelting: An experimental and practical examination of the circumstances which determine the capacity of the blast furnace, the temperature of the air and the proper condition of the materials to be operated upon."

Twelve years later he published a second work, "Principles of the Manufacture of Iron and Steel."

These two books made his name as a metallurgist in scientific circles, and it is not surprising that numerous honours from the learned societies of England and America fell to his share. Among others may be mentioned the Gold Medal of the Society of Arts and the Bessemer Gold Medal of the Iron and Steel Institute. Of the latter body he was ever a warm supporter. He was instrumental in its foundation, and in 1873 succeeded Sir Henry Bessemer as its third President. He was an Hon. D.C.L. of Durham University, LL.D. of Edinburgh and Dublin, and D.Sc. of Leeds University.

Of his municipal and political work, little need be said. He was for many years a Councillor, and then an Alderman, of Newcastle-on-Tyne, and was

Mayor of the city on two occasions, one of his terms of office being for 1863, when the British Association visited Newcastle, Lord Armstrong being President. As a Liberal he sat in Parliament for a short time, representing the Borough of Hartlepool, and previous to this he had unsuccessfully contested the Northern Division of the County of Durham.

Apart from his own business he devoted much of his time, especially towards the end of his life, to the affairs of the North-Eastern Railway Company. Only a short time before his death he published an exceedingly useful volume, the result of his investigations on the life of a steel rail.

He served on more than one Royal Commission, and was a Government Commissioner or Juror for most of the International Exhibitions for the last thirty years. In the year 1885, to mark his services to the State, he received the honour of a baronetcy.

Little remains to be said: his latter years were spent at Rounton Grange in Yorkshire, a place which he purchased early in the seventies. Time seems to have dealt very gently with him, and though he reached a great age, his faculties, with the exception of his eyesight, were almost unimpaired. During the last year of his life he failed somewhat, and finally on December 20, 1904, in his eighty-ninth year, he passed away full of years and of honour.

A. N.

FRANK McCLEAN, 1837—1904.

Frank McClean, who died at Brussels on November 8, 1904, was born at Belfast on November 13, 1837. He was the only son, in a family of six, of John Robinson McClean. Mr. McClean, senior, was a civil engineer and Fellow of the Royal Society. His eminence in his profession and his reputation as a man of sound judgment are indicated by the fact that he was a member of several Royal Commissions. His advice was also sought by the Emperor Louis Napoleon about improvements in the City of Paris, and he was one of the English engineers who urged the completion of the Suez Canal at a time when the abandonment of that great work was contemplated by the Khedive.

Frank McClean was educated at Westminster School up to the age of sixteen, and went thence to Glasgow University, where he came under the influence of Sir William Thomson, now Lord Kelvin. In 1855 he entered at Trinity College, Cambridge; he became a scholar of the College and was a Wrangler in the Mathematical Tripos of 1859. Immediately after taking his degree he became a pupil of Sir John Hawkshaw and was employed on the drainage works of the Fen Districts of the Eastern Counties. In 1862 he was made a partner in the firm of McClean and Stileman and assisted his father in the survey made for the railways in Moldavia. Shortly afterwards he became resident engineer of the Barrow Docks and of the Furness and Midland Railway and acted in this capacity for about four years. In 1865 he married Ellen, the daughter of Mr. John Greg, of Escowbeck, Lancaster, and for the next four or five years lived in London, working in the office of the firm; but in 1870 he withdrew from the active pursuit of his profession and went to live at Ferncliffe, Tunbridge Wells.

Here he found quiet and leisure for congenial studies and for scientific research, and he devoted himself quietly and methodically to work. As an example of his thoroughness, it may be mentioned that on finding his studies seriously impeded by his ignorance of foreign languages, he mastered both French and Italian in his thirty-fifth year, and he read widely in ancient and modern history. He travelled much on the Continent and knew the principal galleries and museums intimately. His own superb collections of ancient coins, manuscripts, early printed books, enamels and ivories were made methodically; he did not collect in a haphazard way, he had an ordered plan, and as far as he could he chose his specimens to illustrate evolution in art. He did not often talk of these matters, but now and then he would open out and let one see the value he attached to the humanizing influence of art, his delight in some finished piece of workmanship and his knowledge of its position and value in the history of artistic development. He thought that scientific men were often too much absorbed in their own special work. Perhaps he felt that his own method of research left him somewhat isolated; for he never employed an assistant, but carried out all the laborious details of his scientific work with his own hands; thus, for instance, in his very brief account of his study of the spectrum of high and low sun, he gives details of the methods he himself employed for the sensitisation of the photographic plates. So, also, his many portfolios of photographic enlargements which he himself made from his original negatives of spectra show how systematically he carried out the tedious processes of manipulation for the sake of being able to put into the hands of other investigators the material which he had gathered together by his own industry. The same sort of activity and system are evidenced by the choice collections which he bequeathed to the University of Cambridge for preservation in the Fitz-William Museum. The manuscripts which he bequeathed are 200 in number and range in date from the eighth to the eighteenth century; and there are besides 230 early printed books. By his bequests the resources of the Museum have been nearly doubled in each of these departments.

Mr. McClean's earliest scientific paper is a note of two pages on the Equations of the Motion of the Moon, published in the 'Quarterly Journal of Mathematics' in 1860; but he did not pursue this line of research, and it is in connection with spectroscopy that he made his mark in science. His first experimental work related to electricity; in 1872 he spent much time in devising and making coils and other electrical appliances, and he made use of them later in his researches on the spectra of metals. Meanwhile, about 1875, he invented the simple and efficient star spectroscope which bears his name. He used it in connection with a 15-inch reflector in making visual observations of star spectra at Ferncliffe. This form of spectroscope is a direct-vision instrument; it is furnished with a slit, which, however, may be dispensed with in stellar observations; in place of the usual plano-convex lens a cylindrical lens is inserted between the slit and the prism, and thus a lengthened image of the slit is formed in its principal focal plane. The observer thus sees a broad spectrum in which the lines can be much more readily detected than in the linear spectrum of a star. Mr. McClean has not given any published account of this instrument, but he had it constructed by Browning; and by reason of its compactness and efficiency, and the ease with which it could be manipulated, it was and still is widely used.

Mr. McClean's first published paper on spectroscopic matters is one relating to his photographs of the red end of the solar spectrum between the lines D and A ('Monthly Notices, Royal Astronomical Society,' 1889, vol. 49, 122–124). He had been for several years previously working at solar observations, and for three years at least, 1879–81, had made records of the positions and drawings of the forms of the notable prominences on the sun's limb. These records survive unpublished, but it is only from a question put to Father Perry at a meeting of the Royal Astronomical

Society in January, 1888, that we learn that he had paid attention to solar phenomena for nine years previously. He remarked at that same meeting that his observations afforded some evidence of the recurrence of prominences at fixed solar longitudes, and that there seemed to be indications that prominences were of a more permanent character than sun-spots. The records, which are fairly numerous for 1879–81, seem hardly to be sufficient to establish this view; the systematic nature of the observations was no doubt interrupted by his building a new house at Rusthall, Tunbridge Wells, whither he moved in 1884. He had arranged the spacious attics of the house, so as to serve as a laboratory, with electrical and other appliances. In the roof was fixed a polar heliostat which reflected sunlight down a telescope which pointed to the pole. By a second reflection the light passed into a diffraction grating spectroscope. This installation was designed for solar studies and for researches on the spectra of the metals. At the west end of the house he erected an observatory containing an equatorial of 8 inches aperture.

It was in 1887, very shortly after the completion of his new house and laboratory, that Rowland's map of the solar spectrum first appeared; this map exhibited the spectrum from wave-length 3200 to 5790. Now Mr. McClean had worked much in the red region of the spectrum, and this part was not delineated in Rowland's first map. In fact, nearly one-half of the visible spectrum remained to be photographed. Mr. McClean devoted himself to carrying out this work, and gave a brief description, in the paper of 1889 referred to above, of the photographic methods adopted, and issued a portfolio of enlargements of the solar spectrum from D to A in seven sections corresponding to those of Ångström's normal solar spectrum. This work was completed in December, 1888, almost simultaneously with the publication of the final edition of Rowland's map, which covers the range 3100–6950. Mr. McClean's work was done with a Rutherford grating from 1879 until 1890. In 1890 he substituted a Rowland plane grating.

Mr. McClean next embarked upon a more extensive piece of work, part of which he carried out and published in the form of a portfolio of "Comparative Photographic Spectra of the Sun and the Metals." Series I relates to the platinum group of metals, and shows the solar spectrum and the spectra of iron, platinum, iridium, osmium, palladium, rhodium, ruthenium, gold, and silver. The range of spectrum shown is from 3800 to 5750; it is divided into six sections corresponding to the sections of Ångström's chart, the scale of the plates being 1 mm. per tenth-metre throughout. Series II deals in similar manner with the metals of the iron-copper group, viz., iron, manganese, cobalt, nickel, chromium, aluminium, and copper. He had begun the work by taking comparative photographs of the sun, iron, and iridium; iridium was chosen in order to get a full spark spectrum of air; iron was chosen "on account of its close correspondence with the solar spectrum, and its thus furnishing the best means of co-ordinating the spectra of the other metals with the solar spectrum."

In November, 1890, Mr. McClean had completed his "Comparative Photographs of High Sun and Low Sun Spectra," showing the absorption lines due to the earth's atmosphere. This paper is the last which he published dealing with solar phenomena.

In 1895, Mr. McClean set up in the observatory on the roof of Rusthall House a fine twin refractor made by Sir Howard Grubb. It was of the pattern used for the astrographic chart and consisted of a 10-inch visual telescope coupled with a 12-inch photographic; it carried also an objective prism of 12 inches clear aperature with an angle of 20°. It was thus in his fifty-ninth year that Mr. McClean embarked with this instrument on a systematic survey of the spectra of the stars brighter than 3½ magnitude in the northern heavens. This survey was completed in 1896, and the general results, together with 17 plates reproducing the spectra of 160 stars, were published in the 'Transactions' of the Royal Society in May, 1898. Meanwhile Mr. McClean had completed the survey of the whole sky by taking his objective prism to the Cape of Good Hope, where Sir David Gill put the astrographic telescope of the Royal Observatory at his disposal. With this he had in six months secured 292 photographs of the spectra of 116 stars. In the Northern Survey one of the results of interest was that the bright helium stars were more numerous, relatively to other stars, near the galactic plane than near its poles. This point was amply corroborated by the Southern Survey. A further result of interest in the latter survey was the discovery of the fact that oxygen is shown by the visibility of several characteristic lines in the spectrum to be present in many of the helium stars.

The Gold Medal of the Royal Astronomical Society was awarded to Mr. McClean in 1899 for the achievement of this remarkable piece of work.

Among his other work may be noticed his researches on the spectrum of the variable star β Lyræ, published in 1896, and his work on Nova Persei, carried out in his sixty-fifth year, and published in 1905, after his death.

Of the inner history of the many munificent gifts and bequests which Mr. McClean made for the advancement of science, it is not easy to speak, for he was reticent about such matters. He showed his affection for his Alma Mater Cambridge by several endowments. First of all, in 1890, he founded the Isaac Newton Studentships; and it was characteristic of him that he declined to allow his own name to be attached to these endowments. The Isaac Newton Studentships were intended to encourage post-graduate study and research in astronomy (especially gravitational, but including other branches of astronomy and astrophysics) and physical optics. The studentships afford opportunities for men to devote themselves for three years to research at a time in their lives when, under ordinary circumstances, it would be necessary to search for other paid employment. The records of the holders of the studentships afford a remarkable testimony to the success of the endowment.

Again, it was Mr. McClean who, as an anonymous donor, gave a considerable sum in 1903 for the augmentation of the stipends of two distinguished mathematical lecturers at Cambridge. By this endowment the Stokes and Cayley lectureships were founded.

In 1894 Mr. McClean proposed to Sir David Gill to provide a large photographic telescope fitted with very complete spectroscopic appliances for the Royal Observatory at the Cape of Good Hope, in order that the attack on celestial problems might be carried on with greater power in the Southern Hemisphere. This equatorial, with large circumpolar motion, is a twin refractor, by Grubb, consisting of an 18-inch visual telescope coupled with a 24-inch photographic telescope. The design embodies suggestions made by Mr. McClean himself. An excellent dome fitted with hydraulic appliances for raising the floor was also provided. At Mr. McClean's desire, the telescope was called the Victoria telescope; he was in hopes that it would be completed in the year of the Diamond Jubilee of the late Queen; but sundry alterations were found necessary in the instrument, and it was only formally installed a couple of years later. He had intended to accompany the British Association to South Africa in 1905, principally with the object of seeing his telescope in use. Unfortunately this intention was frustrated, for he was overtaken by illness at Brussels on his way home from abroad; pneumonia unexpectedly developed, and he died at Brussels on November 8, 1904, in the 67th year of his age.

It was not merely during his lifetime that he was a generous benefactor of science. On his death it was found that he had left large bequests to be devoted to the improvement of the astrophysical equipment of the Cambridge Observatory: to the University of Birmingham (in which he had already shown his interest by liberal subscriptions during his lifetime) for the department of physical science: to the Royal Society: to the Royal Astronomical Society: and to the Royal Institution.

Mr. McClean received the honorary degree of LL.D. from the University of Glasgow in 1894. He was elected a Fellow of the Royal Society in 1895, and was for many years a Fellow of the Royal Astronomical Society, and a member of the Institute of Civil Engineers.

H. F. N.

ALEXANDER WILLIAM WILLIAMSON, 1824–1904.

Among the chemists engaged, in the middle of the nineteenth century, in developing the molecular theory of chemical reactions, it was Alexander William Williamson who established that theory on a foundation of experimental facts. His earlier researches on bleaching salts and on Prussian blue are of exceptional value and interest, but it is for the effect upon chemical theory of his other researches and essays that Williamson's name will remain eminent in the annals of chemistry.

Williamson did all his memorable work well within the first half of his life, indeed almost within the first third. His communications to learned societies concerning this work occupy so small a volume, notwithstanding their great significance, that an analysis of their contents can fortunately be included in this account of his life, without altogether exceeding the limits within which it must be confined. Usually, in preparing a biographical notice, famous investigations may be taken to be well enough known to make mention of them all that is necessary, but of Williamson's work a more particular account than that seems called for. There is, it would seem, at the present time, an insufficient realisation of what exactly Williamson did for chemistry, attributable, no doubt, to the fact that his efforts were directed to the replacement of notions, now almost obsolete, by those which have become part of the accepted theory of chemistry, as well as to the fact that the substances upon which he worked are among those which are best or most familiarly known, namely, bleaching powder, Prussian blue, and alcohol.

Of Scottish descent, Williamson was born at Wandsworth, in London, on May-Day, 1824. His father, a man of unusual force of character, was a clerk in the India House, but must have retired, with pension and private means, some fifteen years after the birth of his son. Williamson's mother was the daughter of William McAndrew, a city merchant; from her training and example he acquired that delicate sense of honour for which he was noted. When Williamson was six years old, the family removed from Camberwell to a house which his father had purchased in Wright's Lane, Kensington. James Mill and his son, John Stuart Mill, lived close by, and the two families formed an intimacy which was maintained for years afterwards. The old residences and gardens in Wright's Lane have long since been destroyed and their sites built over. At a date unknown, but probably coincident with that of his father's retirement from the East India Company's service, the family went abroad and resided for many years, first in Paris and then near Dijon. He attended day schools in Kensington, and apparently in Paris, and was a pupil at the College at Dijon. At Dijon also he and his sister, Antonia Helen, two years his senior, had private lessons. Concerning these, the tutor's report was that the young lady had worked steadily, but that of her

ALEXANDER WILLIAM WILLIAMSON.

brother as much could not be said.* Later on, Williamson spent a winter at Wiesbaden, working diligently at German. He spent three years (1841–4) at Heidelberg, where he went to study medicine at the wish of his father. He attended Tiedemann's lectures there ; but the professor was then very old, and Williamson, finding the lectures intensely dull, spent much of the hour in conversation with Moleschott (to be well known later as a physiological chemist) and other fellow-students. On the other hand, he became greatly interested in his work in Gmelin's laboratory and with the lectures on chemistry. From the very first Gmelin was most kind and courteous, and later on he took the greatest interest in his successes. Williamson always spoke of Gmelin with the greatest respect and affection, and soon informed his father that he wished to be a chemist. The latter showed much annoyance, but, seeing that his son was determined, he wrote home to a relative to ask him whether there was any opening for a chemist in England. It will excite no surprise to hear that the answer returned was—"None at all." Williamson was also discouraged at first by Gmelin himself, who told him that it was not likely that he could succeed as a chemist, because of certain bodily imperfections. From earliest infancy he had lost much of the use of the left arm through stiffness of the elbow ; and he had also been deprived of sight in one eye, and left very short-sighted in the other. It was not long before Gmelin had changed his opinion, and therefore allowed himself to tell Williamson's mother that her son "would be chemist." The mother being won over to her son's wishes, the father at length gave way.

Williamson next went to Giessen to study under Liebig. In six weeks' time (May, 1844) he was working daily in Liebig's laboratory, and rising early each day to attend Bischof's lectures on physiology, then his favourite science next to chemistry. During his stay in Giessen he boarded with the family of Dr. Hillebrand, Professor of Literature in the University. His associates were always his seniors, and his letters to his father at this time exhibit him as the serious and hard-working student, to whom even his recreations counted more as aids to better working than as enjoyments. It must be remembered that he had had no English school or college life worth considering, and that he was not bodily fitted to join in youthful sports.

Referring to Liebig in one of his letters, Williamson expresses the opinion that the eminence which that chemist had then reached, was due as much to his pleasing manner as to the undoubtedly great importance of his discoveries. There was to be added to this, he continues, that everyone coming in immediate contact with him could not but be captivated by the expression of benevolence or of affection which a look of his could convey.

Thirty years afterwards, in his Presidential Address at Bradford to the

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* In the obituary notice of Williamson in the 'Journal of the Chemical Society,' Professor Carey Foster gives an interesting reminiscence of the striking personality of Antonia Williamson, to whom her brother through life showed the warmest attachment.

British Association, soon after the death of Liebig, he said of him and of these days in his laboratory, "I think it is not too much to say that the Giessen laboratory, as it existed some thirty years ago, was the most efficient organisation for the promotion of chemistry which had ever existed. Picture to yourselves a little community, of which each member was fired with enthusiasm for learning by the genius of the great master, and of which the best energies were concentrated on the one object of experimental investigation."

First Paper: Bleaching Salts, Catalytic Action.—While at Giessen, Williamson, at the age of 20, published in London, in the *Memoirs of the Chemical Society* (1844), the results of his first research. More as an exercise than for purposes of investigation, Liebig set him to work upon the subject of the "bleaching salts" which had recently been receiving attention in France, and even in Germany in the Giessen laboratory itself. He soon obtained results quantitatively at variance with those recorded by others, and came upon a fact which, in his own words in a letter to his father, "will throw a much-needed light upon the composition and properties of one of the most interesting salts, not only to the chemist but to the public." To Williamson's mortification, Liebig at first discredited these results as too improbable, but he was eventually convinced, exclaiming, to his pupil's delight, "Ei, das ist ja charmant, das ist allerliebst; jetzt bin ich erst überzeugt."

It may be of interest to record some words of Williamson's concerning the execution of this research. Writing of his solitary walks on Saturday afternoons, he says: "I often find such a walk of as much real service to me in my progress as a whole week's labour (in the laboratory). The great difficulty in a research such as that I am now pursuing consists not so much in performing the experiments once fixed upon, as in inventing and choosing from those most calculated to attain the desired object."

The great value of this paper, which is entitled "Decomposition of Oxides and Salts by Chlorine," as a contribution to the knowledge of the way in which bleaching salts in solution pass into chlorate, seems to have been entirely overlooked. Yet no one, after Balard and Gay-Lussac, has thrown more light upon the chemistry of chlorine in interaction with bases than Williamson.

As ordinarily carried out, the production of a chlorate is the result of the catalytic action of chlorine upon the hypochlorite present in the solution of (so-called) chloride of lime or similar bleaching salt; this Gay-Lussac had already explained. But Williamson succeeded in showing, in the first place, that, after the chlorine in presence of water has combined with an alkaline earth or an alkali to form chloride and hypochlorite of the metal, still as much more of it can be made to dissolve in the solution by converting the hypochlorite itself into chloride, along with hypochlorous acid, and with but very little formation of chlorate. In the next place, he found that this solution of metallic chloride and free hypochlorous acid can be made by heat to pass into that of chlorate equivalent in quantity to half of the chloride, with the liberation of as much chlorine as had been absorbed by the bleaching solution. To make his proof of this the more convincing, he dissolved some potassium chloride in a strong solution of hypochlorous acid, and by heat changed this chloride into chlorate and free chlorine, thus establishing what had seemed to Gay-Lussac (1842) to be most unlikely. To-day, the possibility of such a remarkable change will be admitted without much hesitation; but 60 years ago, quite possibly, chemists hesitated to accept results obtained by a 'prentice hand in chemistry which were not in accordance with the opinion of such an authority as Gay-Lussac. Nearly 40 years later (1883), Lunge and Naef, evidently unaware of what Williamson had done, succeeded in showing that, even in the cold, hypochlorous anhydride freely decomposes solid hydrated calcium chloride by converting part of it into hypochlorite.

Finally, Williamson proved (contrary to what Liebig had with approval allowed his English pupil, Detmer, to publish in the *Annalen*) that hypochlorous acid, which so readily decomposes a chloride, cannot decompose a dissolved alkali carbonate or bicarbonate. By this, as he pointed out, it is shown that, in the copious production of a chlorate which may follow upon the passage of chlorine gas through a solution of potassium or sodium bicarbonate, the production of the chlorate depends solely upon the interaction of the first-formed alkali chloride and hypochlorous acid.

This research of Williamson's appears to be the first successful attempt to throw light upon the nature of a catalytic action, such as had been here presented by Gay-Lussac. It was soon to be followed by a second one in the case of what is known as etherification.

Ozone.—A second paper quickly followed that on chlorine. It is entitled, "Some Experiments on Ozone,"* and purports to have proved that ozone is a peroxide of hydrogen. Ten years afterwards, however, Andrews and Tait proved that ozone is not a compound at all. Williamson had worked with a mixture of ozone and oxygen electrolytically obtained, and these mixed gases, we must assume, had not been kept quite free from electrolytic hydrogen.

Prussian Blue.—Very soon after the appearance of the paper on ozone, Williamson published his important research on the composition of Prussian blue. This beautiful preparation was then of special interest as a salt, in the constitution of which one and the same element, iron, functions partly as basic and partly as acid radical. It had been easy to ascertain that it is composed of both ferrous and ferric cyanides and of potassium cyanide, and that the proportions of these cyanides are inconstant in it. It had also been possible to foresee, with some confidence, that among its component substances, there must be present the two cyanides of iron, formulated respectively by $Fe_7C_{18}N_{18}$ and $Fe_5C_{12}N_{12}$, but it had hitherto not been possible to verify this inference. For, Prussian blue, being amorphous and highly colloidal, is incapable of being separated into the several substances of which it is a mixture.

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* 'Mem. Chem. Soc.,' 1845, vol. 2, p. 395.

Williamson succeeded in actually preparing both the above indicated iron cyanides in a state remarkably near to purity, notwithstanding their colloidal nature. He also produced a new blue salt, a constituent likewise of Prussian blue, a double cyanide of iron and potassium, $KFe_2C_6N_6$, by the limited oxidation of the insoluble, nearly white, potassium ferrous cyanide $K_2Fe_2C_6N_6$, known as Everitt's salt. The new salt, since obtained in various ways, has proved to be of perhaps greater interest than either of the other constituents of Prussian blue, namely, Turnbull's blue, $Fe_5C_{12}N_{12}$, and the substance, $Fe_7C_{18}N_{18}$, which chemists often still call "Williamson's blue." One thing which gives it interest is the fact that it is the parent salt of both Turnbull's and Williamson's blues, being always, as Skraup has shown (1875),* the precipitate first to form, whether a ferrocyanide be mixed with a ferric salt or a ferricyanide with a ferrous salt, so that, as a consequence, well-washed and freshly prepared Prussian blue is always a mixture of these three blue salts and of these only. Another point of interest about Williamson's new salt is the remarkable readiness with which it usually passes into a form freely soluble in water. It appears to be possible, indeed, to get all three blue constituents of ordinary Prussian blue into solution in water, but such dissolution of two of them only exceptionally occurs; whereas the other one, that obtained by Williamson, $KFe_2C_6N_6$, is usually found to be so soluble in water as to have become known as "soluble" Prussian blue, and is only obtainable in a form insoluble in pure water when it is prepared by Williamson's method.

One other matter of importance comes out from Williamson's researches on this subject, which is that, when potassium ferrocyanide in solution is digested with Prussian blue, the ferric cyanide in each of the three blue salts which together constitute it, will always take potassium cyanide from the ferrocyanide and thus become potassium ferricyanide in solution, whilst in its place there will be left an insoluble pale blue substance containing all the ferrous cyanide together with some of the potassium cyanide of the potassium ferrocyanide, apparently as Everitt's salt. Williamson proposed in this way to manufacture potassium ferricyanide in a state of purity.

From the account just given it will be seen that this paper on the compounds of cyanogen and iron must be ranked as a classic memoir on the subject. It was read at the meeting of the Chemical Society, held on March 16, 1846.

After carrying out the three researches just described, Williamson left Giessen and took up residence in Paris in July, 1846, where he remained until his return at last to London in June, 1849. Arrived in Paris, and being already familiar with the French language, he at once arranged for lessons in mathematics with Auguste Comte. Writing to his father in eulogy of Comte, he said, "If my experience of Comte's superior powers were insufficient to convince you that his lessons were worth their price, John (Stuart) Mill's saying that he 'would prefer him to any man in Europe to finish a scientific education,' ought to carry the point and to induce you to consent to my continuing as I have begun." Williamson seems to have made good use of these lessons, for before the end of the year he was himself teaching an English youth mathematics. Comte was much pleased at this, and remarked that teaching was the best possible means to perfect one's own knowledge.

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* Recent valuable work by Karl Hofmann and his colleagues on Prussian blue (1904–5) is essentially confirmatory of that of Williamson and of Skraup.

During Williamson's three years in France he published nothing of importance and seems not to have attempted any chemical researches. But it was probably in these years that he began that cordial acquaintance with Laurent, Gerhardt, Dumas, and other French chemists which continued throughout their lives. After his marriage, there was a close intimacy between the Williamson and the Wurtz families and also with the Berthelots, and with Cornu.

On the death of Fownes, Williamson, in 1849, was unanimously elected to the Professorship of Practical Chemistry in University College, London, and thus came under the influence of Thomas Graham, who at that period held the Chair of General Chemistry.

During the next five years he elaborated the great work of his lifetime publishing the results of it in varying detail at meetings of the British Association, the Chemical Society, and the Royal Society, and in the 'Philosophical Magazine' and the 'Chemical Gazette.' Of these researches, first came those included under etherification, and later those on the constitution of salts.

Etherification (1850-52).—The expectation that in chemical reactions substances would generally beget others similar to themselves, induced Williamson to make an experiment, soon to become celebrated, in which it was anticipated that a new alcohol could be derived from ordinary alcohol. To his "astonishment," it yielded him common ether instead of a new alcohol. The experiment had been a simple one, its result had not met his anticipations, and it had not even been productive of a new substance; but the nature of his interpretation of the result of it quickly made his name famous with chemists. To begin with, he had seen that his experiment had solved, for him at least, the long-vexed question of the relation of three substances of such fundamental importance in organic chemistry as alcohol, ether, and water, and thereby had determined the true proportions of their atomic quantities or, as we now say, their molecular quantities. It had afforded, besides, a confirmation and proof of the views of Laurent and Gerhardt, comparable to that which was, long after, to be given of the truth of the theory of the periodicity of the elements by Lecoq de Boisbaudran's discovery of gallium. In this way it was destined to do more than anything else in showing how futile was any further opposition by the old school of chemists to the adoption of Gerhardt's system of equivalent quantities now known as molecular quantities. Next, it gave Williamson the basis of his theory of etherification, in which is contained the origin of chemical dynamics, the theory of ionisation, the theory of catalytic action, and the grounds for reconsidering Berthollet's law of mass action, which had fallen into neglect. Lastly, but perhaps before all in ultimate importance, it led Williamson to form his theory of the constitution of salts, in which is included the foundation of the doctrine of valency and the linkage of radicals.

Some account of his experiment must be given, in order to make his theory clear. He had converted some alcohol partly into ethyl iodide and partly into potassium ethoxide (or ethylate), the former being reconvertible to alcohol by means of moist silver oxide, and the latter by merely dissolving it in much water. He then found that these substances interact with each other in proportions derived from equal quantities of alcohol, and that the products are the substances, ether and potassium iodide. Either of these is derived from both ethyl iodide and potassium ethoxide, and therefore its quantity is chemically equivalent to that of the ethyl iodide or that of the potassium ethoxide. But the two reacting substances are each equivalent to the quantity of alcohol from which they are derived. From this it follows that *two* equal quantities of alcohol are concerned in the production of ether, and that the quantity of it produced is equivalent to either of the two quantities of alcohol. Nowadays, for equivalent the word molecule is used, but the sense is unaltered. Williamson's experiment would doubtless by itself not have proved convincing to many chemists at that time. They would have met it with the apparent contradiction afforded by the fact that alcohol is decomposed into ether and water, in quantities together equal to it in weight and composition, when it is run into sulphuric acid already mixed with alcohol and water in such proportions as to allow the heated mixture to boil at 140°. For, from this fact it would seem just as reasonable to assume that the alcohol, which decomposes into equivalent quantities of ether and water, is itself equivalent in quantity to that of either of its educts, as it is to assume that the ether produced in Williamson's own experiment is but one equivalent or molecule instead of two. But Williamson's papers forestalled in two ways the bringing in of this fact as adverse evidence; first, by the accounts of other experiments which they contain, and, secondly, by the theory of etherification put forward in them. It is important, however, that it should be recognised that the result of his single experiment is really sufficient to establish his point. That experiment in itself indicates that, in the ordinary ether process, there are to be recognised *two* molecules, two equal and distinct quantities, of alcohol which, by their mutual exchange of ethyl and hydrogen, give rise to the ether and water, one molecule of each.

The results of Williamson's other experiments strengthen the argument, but are themselves unconvincing if the result of his first experiment is so. One set of these experiments, in which he prepared mixed ethers, such as methyl ethyl oxide, consisted in letting the iodide derived from one alcohol interact with the potassium derivative of another alcohol. The other set was made up of those in which, in different ways, the mixed ethers are obtained, by using two different alcohols in carrying out the ordinary or continuous etherification process by means of sulphuric acid.

The production of mixed ethers, substances which prove themselves by their composition to be derived from the two alcohols used, shows the propriety of regarding ordinary ether as being all derived from both the ethyl iodide and the potassium ethoxide, instead of half of it coming exclusively from one of these substances and half of it exclusively from the other. Their production served another purpose, because Williamson had found that the same mixed ether was produced, whichever of the two alcohols was used as the potassium or as the iodine derivative. For, from this fact it follows almost necessarily, that the ethers are oxides of two hydrocarbon groups and not of a complex of the two. Williamson has not indeed expressed his views in this way, but as he started his experiments under the belief that the hydrogen of alcohol is or may be all united directly to the carbon, herein following Berzelius, he must have been influenced by some such reasoning when he represented alcohol as the oxide of ethyl and hydrogen, and ether as the oxide of two atoms of ethyl.

The molecular weights thus found by Williamson for alcohol and ether were the same as those assigned to them by Gerhardt on the assumption that molecular quantities of different substances have the same volume in the gaseous state under like conditions. They therefore gave such support to Gerhardt's views as to weaken greatly, as was just now said, the doubts entertained as to the substantial correctness of these views. Other experimental verifications, as is well known, quickly followed, so that in a few years Gerhardt's assumption led to the revival in full force of the rule or hypothesis of Avogadro which, at the time of Williamson's experiments, was well-nigh forgotten, so little had it appealed to chemists for want of sufficient experimental support. It was also largely due to the effect produced by Williamson's experiments and the interpretation he gave of them that the notion of molecules as being the true equivalents, and of their component atoms as being subordinate to them, obtained general acceptance, a notion for the conception of which chemistry is also indebted to Avogadro.

Catalysis or Contact Theory.—When Williamson made his famous experiment there were in the main two views current as to the nature of the process of making ether from alcohol by means of sulphuric acid. Mitscherlich's view, upheld by Williamson's colleague, Graham, was that by contact with hot sulphuric acid (or perhaps by contact with sulphovinic acid), and by virtue of a catalytic force rather than by the influence of any play of chemical affinities, the alcohol decomposed into water and ether, the catalysing acid, whichever it was, remaining chemically unchanged. The other view was that the production of ether was due to decomposition, by heat, of sulphovinic acid (ethyl hydrogen sulphate) into sulphuric acid and ether, followed by the production of fresh sulphovinic acid by the union of alcohol with sulphuric acid. This view was Liebig's, in whose laboratory Williamson had been trained. Both accounts were made up of facts, hypothesis, and error; neither could be dignified with the name of theory, for neither offered any sufficient explanation. In propounding his theory, the one and only theory that has been framed, Williamson was careful repeatedly to point out that he was combining the theories of his two eminent seniors in his own, but it is clear that the enunciation of his own theory implies the rejection of the essential points in both of their theories. The catalytic phenomenon is a patent fact; but the existence of a catalytic force, and the activity of a contact which brings about chemical change without the contact substance being affected, are both to be cast aside as baseless fancies. The production of sulphovinic acid is also a fact not to be denied; the decomposition of the acid into ether, by heat and by itself, is only imaginary.

Williamson's description of etherification is that a molecule of alcohol reacts with a molecule of sulphuric acid to form ethyl hydrogen sulphate and water, and that then a second molecule of alcohol reacts with this ethyl hydrogen sulphate to become ether and sulphuric acid again, this pair of reactions being ever and again repeated, so long as the conditions are that the ether and water produced are being removed and replaced by fresh alcohol. In this way it is made evident that the quantity of alcohol which gives a molecule of ether and a molecule of water must be treated as being not one but two molecules. Here, it will be seen, is given, for the first time fully (but see p. xxvii) the form of explanation, now universally accepted, of all catalytic action.

Chemical Dynamics.—To complete his theory, Williamson points out that whilst the two double decompositions involved are, in themselves apart, perfectly conformable with others, the fact of their alternations and continuous successions is something obviously independent of the exercise of chemical affinity, and inconsistent with the supposition that the atoms of a compound are in a state of rest. There must therefore be a dynamical treatment of chemical phenomena, in which the degree and kind of motion possessed by atoms must be studied, and the element of time be taken into consideration. The alternating changes of sulphuric acid and sulphovinic acid into each other cannot be attributed to any exercise of superior affinity, for one moment sees replaced by hydrogen the ethyl which during the preceding moment had replaced a hydrogen atom. Nor can it be referred to the action of some occult catalytic or contact force. It happens because the atoms are not at rest and confined within the molecule, but are constantly changing into other molecules, there taking the place of like or similar atoms. In completing his theory of etherification in this way, Williamson, as is universally admitted, placed the dynamical idea of chemistry on a definite concrete foundation. In a lecture on the subject at the Royal Institution, he expressed himself, as follows, in words which recall the opinion pronounced by Robert Boyle in the infancy of the science:—"The dynamics of chemistry will commence by the rejection of the unsafe and unjustifiable supposition that the atoms of a compound are in a state of rest, will study the degree and kind of motion which atoms possess, and will reduce to this one fact the various phenomena of chemical change." In another place in this lecture he says:—"There are many *primâ facie* evidences that time is necessary for chemical action, but this fact has not as yet entered into the explanation of phenomena."

Ionisation.—It is evident, too, that in the theory of etherification he foreshadowed the modern notion of ionisation. This may be seen in what precedes, but the following quotation seems too interesting as an illustration of the point for it to be omitted:—"A drop of hydrochloric acid being supposed to be made up of a great number of molecules of the composition ClH,... each atom of hydrogen does not remain quietly in juxtaposition with the atom of chlorine with which it first united, but, on the contrary, is constantly changing places with other atoms of hydrogen or, what is the same thing, of chlorine. . . . Suppose we mix with the hydrochloric acid some sulphate of copper, the basylous elements, hydrogen and copper, do not limit their change of place to the circle of the atoms with which they were at first combined, the hydrogen does not merely move from one atom of chlorine to another, but in its turn also replaces an atom of copper, forming chloride of copper and sulphuric acid." More might be quoted with advantage, but what is here given will be enough to show that, whatever may be the ultimate view adopted on the subject of ionisation, Williamson played an important part in the development of the conceptions on which the theory is based.

Mass Action.—Following up his illustration, just quoted, with another in which sulphate of silver is used instead of sulphate of copper, for the sake of the example it affords of the precipitation of an insoluble compound, he refers to Berthollet's view about mass action, and gives new life to it by accounting for the existence of mass action between substances constituted of atoms as an action due to the innate motion of these atoms carrying them from molecule to molecule.

Structural or Positional Formulæ.—In discussing the facts concerned in the production of ether, Williamson showed, for the first time, how chemical formulæ might be so written as to represent chemical constitution as an arrangement and interdependency of atoms, formulæ thus constructed being what are now known as "structural" formulæ. He then developed the subject in papers on the constitution of salts, the anhydrides of monobasic acids, and sulphuryl hydroxychloride.* This method, of expressing by symbols the conclusions to be drawn from the results of experiments as to the chemical constitution of substances, has turned out to be a veritable "calculus of chemical operations," the importance of which to the progress of chemistry can hardly be overestimated.

When Williamson began to publish his views, Gerhardt had already introduced his unitary synoptic formulæ, the nature of which may, perhaps, be best indicated by calling them "agnostic" formulæ. For they were formulæ, the purpose of which was to make no vain attempt to indicate chemical constitution, but to express as simply as possible only the ultimate chemical composition of equivalent quantities of substances. Gerhardt and Laurent did not deny that substances do have atomic structure, but they denied that we could expect to make out anything about it. Such notions concerning chemical constitution, as that nitre consists of and contains potash and nitric acid, and that alcohol consists of ether and water combined together, had been shown by them to be unwarranted assumptions, but were still current.

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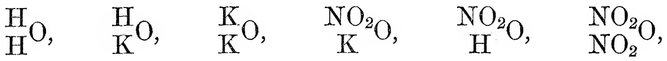
* "On the Constitution of Salts" (1851); "On Gerhardt's Discovery of Anhydrous Organic Acids" (1853); "Note on the Decomposition of Sulphuric Acid by Pentachloride of Phosphorus" (1854).

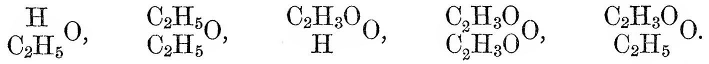
What Willliamson wanted—instead of Gerhardt's synoptic formulæ of reactions, and of the ill-conceived constitutional formulæ which they were intended to replace—were such formulæ as might* be used as an actual image of what we rationally suppose to be the arrangement of constituent atoms in substances, between which decomposition may be effected by the exchange of a radical in the molecule of one substance for a radical in the molecule of another substance. Now, in order to describe, by means of a chemical equation, the process by which the change is effected, in the reaction of one substance with another, that change should be represented by the juxtaposition of the formulæ of the reacting substances, and by then indicating in these formulæ what takes place in the interchanging substances. The adoption of such a method necessitates a reference to types, from which, by the replacement of certain elements or radicals, the constitution of substances of increasing complexity can be deduced.

Williamson took the constitution of water to be the structural type of salts and of classes of substances apparently allied to them, and constructed formulæ for water and for each of these substances in which the three symbols or, in case there were more, three groups of symbols, are so spaced out as to represent by their relative positions always the same structural relation, whatever that may be, in each of them. Thus



$$\begin{matrix}H\\H\end{matrix}O,\quad \begin{matrix}H\\K\end{matrix}O,\quad \begin{matrix}K\\K\end{matrix}O,\quad \begin{matrix}NO_2\\K\end{matrix}O,\quad \begin{matrix}NO_2\\H\end{matrix}O,\quad \begin{matrix}NO_2\\NO_2\end{matrix}O,$$

are his formulæ for water, caustic potash, potassium oxide, nitre, nitric acid, and nitric anhydride. Similarly, to alcohol, ether, acetic acid, acetic anhydride, and ethyl acetate, he gave the formulæ



$$\begin{matrix}H\\C_2H_5\end{matrix}O,\quad \begin{matrix}C_2H_5\\C_2H_5\end{matrix}O,\quad \begin{matrix}C_2H_3O\\H\end{matrix}O,\quad \begin{matrix}C_2H_3O\\C_2H_3O\end{matrix}O,\quad \begin{matrix}C_2H_3O\\C_2H_5\end{matrix}O.$$

These triangulated formulæ are now usually unfolded into straight-line formulæ, thus

$$HOH, \qquad KO(NO_2), \qquad (C_2H_5)OH, \qquad (C_2H_5)O(C_2H_3O);$$

but are otherwise unaltered.

The Linkage and Valency of Radicals.—It was the significance given by Williamson to the relative *position*, to the "juxtaposition," of the three symbols or groups of symbols, which constituted the essential novelty and the importance of these formulæ as constitutional formulæ. It is clear what that significance was to him. For instance, as regards alcohol, it was that one-sixth of its hydrogen is "held" united to the carbon and rest of the hydrogen by its atom of oxygen; that in potassium acetate, half the oxygen serves to "hold together" the potassium with the rest of the salt. Again, sulphuric acid is a dibasic acid, *because* the radical sulphuryl (SO_2) holds together two atoms of hydroxyl. Carbonyl (CO) is given by him as another example of a radical which, in the carbonates, replaces two atoms of the hydrogen of a doubled molecule of water, and thus holds together the two substituted water residues or metalloxyls, thus, $\begin{matrix}KO\\KO\end{matrix}CO$.

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* The next 11 lines are almost in Williamson's own words.

Thus was enunciated for the first time the fundamental part of the doctrine of the linkage of atoms and the valency of radicals. Later on, he gave experimental evidence that sulphuryl is bivalent in sulphuric acid, of the same convincing kind as that he had given of the bivalency of oxygen in alcohol, ether, and water. It consisted in the application of the discovery he had made of sulphuryl hydroxychloride, and of its production from sulphuric acid by means of phosphorus pentachloride (p. xxxvi). In his description of this production, he showed himself already (1854) discarding anything there might be in the presentation of the water type which is outside this theory of the existence and linking power of multivalent radicals. Again (later in 1854) he showed the same thing, when he pointed out that the remarkable substance, ethyl orthoformate, "may be equally well conceived to be a body in which the (oxylic) hydrogen of three atoms of alcohol is replaced by the tribasic radical of chloroform, as (to be) one in which the chlorine of chloroform is replaced by peroxide of ethyl (ethoxyl)."

Confining, as he did, his attention to the water type, the only elemental atom or radical he exhibited, as exercising linking power, was oxygen. Odling and, pre-eminently, Frankland extended the conception to several other elements, but it was not till Kekulé recognised that, in the case of carbon in organic compounds, atoms of the same element may be united directly together, that the real and supreme value of Williamson's conception became evident, and the reference to compound radicals and types to be no longer necessary.

Gerhardt added three other types to Williamson's water type, but all were to him no more than "types of double decomposition," and wanted therefore that structural significance which they had for Williamson.

Just as the latter was led by his water-type formulæ to differentiate one atom of the hydrogen of alcohol from the other five, so was he quickly afterwards led to separate the oxygen of acetic acid into one atom as being that of water, and the other as being within the radical, acetyl (his "othyle"). This procedure was at once justified by the discovery (by a method similar to that employed by Williamson in connection with ether) of the monobasic acid-anhydrides by Gerhardt, who had himself previously deemed their existence impossible.

To bring out the fact more strongly that Gerhardt's type formulæ were no anticipation of Williamson's structural formulæ, it may be here recalled to mind that, in 1863, Playfair advocated the reference of salts to the type of hydrogen peroxide as more appropriate than Gerhardt's reference of them to the type of water, giving a sufficiently plausible presentation of the subject, quite worthy of consideration until the views of Williamson as to atomic structure are applied to show the futility of Playfair's proposal. It is of interest to note further that Gerhardt, before Williamson had worked upon etherification, had gone so far as to regard ether and alcohol as the normal and acid esters of water, water being treated as a dibasic acid, and yet had wholly missed the point of the relationship afterwards brought out and formulated by Williamson. Gerhardt wrote the formulæ of ether and alcohol as $(C_2H_4)_2,OH_2$ and $C_2H_4,OH(H)$, in order to represent this view of their relationship. These instances from Gerhardt's writings serve to illustrate how entirely original were Williamson's notions concerning the chemical constitution of salts and other substances.

Kekulé, who spent the session 1853–54 in Stenhouse's laboratory at St. Bartholomew's Hospital, and passed much time in intimate companionship with Williamson, carried out at that time a research* on thiacetic acid, which afforded a beautiful confirmation of the correctness of Williamson's action in formulating acetic acid with half its oxygen in the radical, acetyl or "othyle." Kekulé showed that by acting upon acetic acid, or its anhydride, or its ester, with phosphorus tersulphide or quinquesulphide, compounds were produced in which only half the oxygen was replaced by sulphur and which had much resemblance to the original acetic compounds.

Substance Distinct from Radical of same name.—Concerning the radicals which he introduced into chemistry, such as sulphuryl and acetyl, and others such as ethyl, the existence of which he accepted, Williamson was careful to point out that they are not to be confounded with the substances or bodies in the free state, which would be indicated by the same names and formulæ. Extending this important distinction, too often still neglected, to metallic and other elemental radicals, he wrote:—"To say that metallic zinc is contained in its sulphate is an expression authorised by usage, but is only strictly true by abstraction from most of the properties of the metal. The material atom which, under certain circumstances, possesses the properties which we describe by the word 'zinc' is no doubt contained in the sulphate but with different properties, and in the chloride with properties different from either; so also of the compound radicals."

Sulphuryl Hydroxychloride; Dibasic Acids† (see p. xxxv).—In spite of the work of Laurent and Gerhardt, the majority of chemists at that time still preferred to consider potassium sulphate as a salt which, like nitre, contains only one atom of potassium, and the acid salt as being potassium sulphate in combination with sulphuric acid. Williamson now placed it beyond dispute that, just as potassium hydrogen sulphate is intermediate to potassium sulphate and sulphuric acid (hydrogen sulphate) in there being replacement of hydrogen by metal or the reverse, so sulphuryl hydroxychloride is intermediate to sulphuryl chloride and sulphuric acid (sulphuryl hydroxide), in the interchange of hydroxyl and chlorine:—

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* 'Roy. Soc. Proc.,' 1854—5, vol. 7, p. 37.

† "Decomposition of Sulphuric Acid by Pentachloride of Phosphorus," 1854.

$$\begin{array}{lll} HO(SO_2)OH, & HO(SO_2)OK, & KO(SO_2)OK \\ HO(SO_2)OH, & HO(SO_2)Cl, & Cl(SO_2)Cl. \end{array}$$

Gerhardt, who had just then prepared chlorides of dibasic acids, had not succeeded in bringing his facts into line with the theory of monobasic acids, which he had adopted from Williamson. The latter's discovery of the substance intermediate to sulphuric acid and its chloride (sulphuryl chloride), and his recognition of its nature as such, rendered evident how this was to be done, and demonstrated the fullness with which the water-type theory met the case. In this way, a material impulse was given to the general adoption of structural or valency formulæ.*

In 1854, several papers upon subjects worked out in his laboratory by assistants and other students, all bearing the impress of his directing mind, were brought by Williamson before the Royal Society. Some of them are of great interest, but space cannot be given for notice of them here. Also, in this year, he read a note before the Royal Society on the magnetic medium.

In 1855, when Graham resigned the Chair of Chemistry in University College on becoming Master of the Mint, Williamson was unanimously chosen in his place, the Senate having decided, at Williamson's strongly urged wish, to combine the Professorships of Chemistry and Practical Chemistry in one person. His researches on bleaching salts and on Prussian blue had gained him his first professorship; now, it was those upon etherification which contributed very largely to his success in getting the second and higher appointment. These researches had just before led to his being made a Fellow of the Royal Society. Three weeks after he had obtained his new position he married Emma Catherine Key (third daughter of his colleague, Professor T. H. Key, F.R.S., also Head Master of University College School), to whom he had been engaged for more than a year. In 1857, he was for a month almost deprived of sight by an explosion in the laboratory.

The session ending with his appointment to the Professorship of Chemistry was the last in which Williamson published papers upon the results of researches by himself, or carried out at his instigation, with the notable exception of those by Sakurai, in 1880–81. This abstention from research work, however greatly to be regretted, is not perhaps much to be wondered at. His mind, indeed, at this time and for years afterwards, teemed with suggestions which, had they been carried out with his own hands, would no doubt have sometimes been fruitful of results though not always those expected. But having to be left to others, competent though they probably were, the facts reached generally caused him to discontinue the pursuit of one idea for that of another, so that a research was rarely brought to a satisfactory conclusion. The same may be said of his later attempts in the applications of chemistry, carried on at his Willesden works.

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* Williamson's papers on Etherification and the Constitution of Salts have been republished in the convenient form of an Alembic Club Reprint (16).

His professorial position made, indirectly, great demands upon his time. He took an energetic interest in the affairs of University College, among other things in forwarding through it the movement to get the University of London to grant Degrees in Science. On the Council of the Chemical Society he served continuously from 1850, becoming President in 1863; and he took a prominent part in the then somewhat frequent and elaborate discussions at its general meetings. In 1859 he began his first term of office on the Council of the Royal Society. In all co-operative work his opinions had great weight with his colleagues and others, in consequence, apparently, of the extent to which he at once saw through difficulties, and of his not being dismayed by opposition. Indeed, as a strenuous advocate of any cause he took in hand, he was always a force to be reckoned with, in movements to be undertaken in which he might be interested. He generally came to occupy a forward, if not the front, place in such a movement.

Williamson was one of the most hospitable of men, and after his marriage was seldom without one or more friends at his table. He frequently entertained foreign guests, among whom may be mentioned J. P. Cooke, Wurtz, Berthelot, Cornu, and Cannizzaro. Everyone at once felt at home with him and Mrs. Williamson, both blest with the most kindly dispositions.

There is yet another reason, and no doubt the essential one, for his comparative neglect, from this time forward, of the field of chemical research, hitherto so brightly illumined by him. From 1854, for several years to come, his mind became occupied with the possibility of generating steam for mechanical purposes in a more satisfactory way than was then being followed. By 1859 he had invented a water-tube boiler, or "tubulous" boiler as he suggested it should be called, to distinguish it from the common form with the fuel gases passing along tubes through the water. He then wrote of his invention as important and as fast approaching completion. Again, in 1862, he called it the best and most important work in his life. This was just after he had taken out letters patent for it. The claim in his patent runs, with slight abridgment, as follows: "The construction of boilers wherein a number of slanting or vertical tubes, each acting as a separate steam generator, are firmly connected to a foundation at their lower ends, and are there made to intercommunicate by having connecting pipes attached to them for supplying the feed water, whilst the upper ends have no rigid connections, and are free to expand in the direction of their length, the steam being conducted, by small curved pipes attached to their upper ends, into main steam-pipes." Stacks of such pipes formed the side-walls of the combustion chamber, and allowed the hot gases to circula round the pipes, so as to raise steam and superheat it. As to what extent Williamson's invention is to be considered as an anticipation of the water-tube boilers now in use with marine engines, it is beyond the competence of the present writer to offer an opinion.

Early in 1863, writing to his father, he referred to his patent and appealed for further pecuniary assistance. His father showed himself unsympathetic and refused help, advising him to leave the invention alone and devote all his abilities to the duties of his professorship.

Towards the end of that year (1863) Williamson received from Mr. Hugh Matheson, of Lombard Street, an offer to send him five young Japanese to be boarded and looked after in matters concerning their education. He was unable to take in more than three of these as boarders, but undertook the general supervision of the education of them all. These young men were destined soon to play important, in some instances most important, parts in the great and practically bloodless revolution whereby the Imperial House of Japan was restored to power, and the country led to adopt and build upon much that it found good in European arts and sciences, forms of government, commerce, manufactures, and education. One of these, now the Marquis Ito, framed the present Constitution; a second, (now Count) Inouye, gave direction to the development of commerce; a third, also named (Viscount) Inouye, established the railway system; and a fourth, (Viscount) Yamao, acting as the first Minister of Public Works, introduced, with the aid of instructors from this country, a system of technological training which has proved to be eminently successful.

Later on, the Prince of Satsuma sent over a party of 16 young Japanese to be placed under Williamson's care, among them being Mori, who became Minister Plenipotentiary both to London and New York, and afterwards a member of the Cabinet in Tokyo. Also of the number, and later on representing their country abroad, were Yoshima and Sameshima.

Williamson took a keen interest in all the work of these pioneers and some of their successors in the development of Japan on the European side of its life. Particularly was he responsible for the selection of the staff of professors to whom was to be entrusted the planning of the technological education of the country. Several letters are still preserved which show how highly were appreciated the efforts made by Williamson in the cause of education in Japan, both through the instrumentality of the statesmen for some time in his charge, and afterwards also in other ways.

In conjunction with Dr. W. J. Russell, Williamson made and perfected, in 1857 to 1864, a great improvement in the analysis of gases by devising the "pressure tube," in which is enclosed over mercury a quantity of air which has its normal volume when the surface of the mercury in the tube stands at a certain mark on the tube. Any gas to be measured being made to stand over a column of mercury of the same height in a tube by the side of the pressure tube, its volume evidently becomes the same as it would be under normal temperature and pressure. By the use of the pressure tube, therefore, the necessity of correcting for atmospheric pressure and temperature is avoided and the process of analysis greatly facilitated. A preliminary notice of the apparatus appeared in the 'Proceedings of the Royal Society' for 1857, but it was not fully described in an improved form until 1864 in the 'Journal of the Chemical Society.'

Williamson's courses of lectures to the students of University College were always of an impressive, suggestive, and interesting character, in spite of the fact that he did not do much to modify them as time went on, in order that they should continue to reflect the rapid developments which chemistry is ever undergoing. He used to say that he had come to look upon his early lecturing as having been much too elaborate and advanced, and to believe in the wisdom of greatly simplifying his teaching. A small text-book published by him, in 1865, served to illustrate what his notion was as to the ground to be covered by a general course of lectures. The courses of practical chemistry, entailing as they did hard work and continuous attention, he had after a few years to leave to be given by his assistants, several of whom have since become eminent. He was emphatically a great teacher, honoured and revered by his pupils.

Williamson gave several lectures at meetings of the Chemical Society: in 1855, on certain processes for the decomposition of fats by water at high temperatures; in 1859, on gas analysis; in 1861, on thermodynamics in relation to chemical affinity; in May, 1864, on the classification of the elements according to their atomic weights; in December, 1864, on chemical nomenclature and notation; and in 1869, on the atomic theory. The last three of these are contained in the Journal of that Society. The subject of the classification of the elements had suggested itself to him through the proposal of Cannizzaro to readopt most of the atomic weights used by Berzelius. Cannizzaro had based his proposal mainly on physical grounds, and Williamson proceeded to summarise the chemical evidence in support of Cannizzaro's system of atomic weights.

In this lecture there occurs Williamson's statement of the grounds for rejecting Kekulé's contention that the atomic valency of each element must be constant. Thoroughly convinced as to chemical valency being variable, Williamson did not hesitate some years later in his address to Section B of the British Association in 1881, and elsewhere, to enlarge the notion in applying it to the multivalency of the dominant element in metallic double salts. He thus, to some extent, anticipated Werner's conception of the "co-ordinating" power of such elements. Representing by symbols the well-known alkali double salts of auric and platinic chlorides as compounds of quinquevalent gold and octovalent platinum, $AuCl_4Na$ and $PtCl_6K_2$, he pointed out the converse analogy of the former with sal-ammoniac, NH_4Cl, explaining that the atom of sodium is not to be regarded as directly united with the atom of gold, but indirectly with it through the chlorine.

The lecture on chemical nomenclature and notation appears to have been given after the attempt at agreement, by a committee of Section B of the British Association appointed to consider the subject, had failed. His recommendations were largely adopted by chemists, and are followed even now to some extent.

Williamson was a convinced believer in Dalton's atomic theory, and held that the results of modern research sufficed to prove its truth. Giving his lecture on the atomic theory from a handful of unarranged notes, he filled the whole time of the meeting with an eloquent assertion of the truth of the theory, holding his large and distinguished audience in unflagging attention. After the summer vacation, another meeting was given up to the discussion of the subject of the lecture. It was a memorable and interesting evening in the life of the Chemical Society. Both lecture and discussion are reported at length in the *Journal*, but the reports give no adequate reproduction of what was said. Frankland, Brodie (in the chair), Allen Miller, Tyndall, Carey Foster, Odling, Mills, C. R. A. Wright, and others took part in the discussion, and the excitement ran high at times. But nothing came of it all, and chemists remain not much less divided on the subject now than they were then.

In 1862 Williamson was the recipient of one of the Royal medals, awarded by the Royal Society in recognition of his work on etherification. In 1863–4 and 1864–5 he was President of the Chemical Society, the latter being the year in which he delivered two of the lectures just noticed. He was again President of that Society in 1869–70 and 1870–71. He had thus the opportunity of inaugurating the Faraday Memorial lectures, of which the first was given in 1869 by Dumas. The next year he made "perhaps the most memorable year in the history of the Society," by starting the publication, in its *Journal,* of monthly reports in the form of abstracts of all papers of a chemical nature, "a work second only in importance to that accomplished by the establishment of the Society. No steps could have more directly promoted the main objects of the Society."

Soon after 1870 he established at Willesden some experimental works for improving and inventing chemical manufacturing processes, and continued them for about eight years. Although his outlay must have been considerable, he arrived at no profitable results. Among other things, improvements in the manufacture of sodium hydroxide are said to have been tried. He also attempted the economic recovery of gold, platinum, and other rare metals from pyrites, by roasting with salt and in other ways.

In 1863, at Newcastle, he presided over Section B of the British Association, his address being upon recent progress in chemistry. He was President of the British Association itself in Bradford, in 1873, taking for the subject of his address the meaning and use of scientific activity and what can be done to encourage it for the advancement of science. He used chemistry to illustrate his views, and gave the atomic theory as the basis of its development and wonderful progress. He again presided over Section B of the British Association meeting in York, in its Jubilee year in 1881, in order that he might trace in his address the history of chemistry since the foundation of the Association, in accordance with the plan of giving that year in each of the sections a history of the science with which it was concerned. From 1874 to 1891 he was the General Treasurer of the British Association.

After serving on the Council in 1859–61 and in 1869–71, Williamson was made Foreign Secretary of the Royal Society in 1873, and continued to hold that office till 1890. He was a particularly able linguist. His earlier papers on chemistry were written by him in German, being intended for but not published in Liebig's *Annalen*, and then translated into English for publication in the Memoirs of the Chemical Society.

In 1876 he was appointed by Sir C. Adderley to succeed Dr. Letheby as Chief Gas Examiner under the Board of Trade.

The Birkbeck Laboratory of University College had for many years proved quite insufficient for the needs of the various classes, to which had been added those in Applied Chemistry. The laboratories now in use were therefore put up under Williamson's direction, and he moved into them in 1880. In this year also a research was carried out under his direction, which was interesting not only on account of its results, but of the Japanese nationality of its author, and of the part which Williamson had already taken in promoting the spread of scientific knowledge in Japan. The research was by Sakurai, now well known to chemists, and eminent in Japan among University professors. He published three papers in the 'Journal of the Chemical Society' on the subject of metallic compounds of multivalent hydrocarbon radicals, two of which were worked out in University College laboratory and the third in Japan. The monomercuric iodide derivative of methane was already known, but Sakurai unexpectedly succeeded in obtaining the compounds,—$CH_2(HgI)_2$, $CH(HgI)_3$, (the metallic analogue of chloroform, $CHCl_3$), and other derivatives which as compounds of bivalent and tervalent radicals were of a new order.

During 1884 and 1886, Williamson took an active part in the discussions about a teaching university for London.

In 1888 he resigned his active appointments at University College where he had been a professor for 39 years, and was elected Emeritus Professor of Chemistry. A portrait of him, by Collier, which hangs in the Council Room of University College, was presented on behalf of the subscribers by Sir Henry Roscoe. Another portrait, painted by Mr. Biscombe Gardner, was presented, 10 years later, to the Chemical Department of the College. A short time before his retirement, that is, in 1886, he had gone to live at High Pitfold, Haslemere, and there began to devote most of his time to farming on scientific principles, only now and then visiting London, but much enjoying the occasional visits of his children and grandchildren to Haslemere. Very slowly his health began to decline, and from this cause he had to absent himself from the Jubilee Meeting of the Chemical Society in 1891. Seven years later, however, he was able by a great effort to attend a banquet given by the Chemical Society on November 11, 1898, to him and the five other Past Presidents, who had then been Fellows of the Society for at least 50 years. He not only attended the dinner, but spoke, as did his colleagues, to the toast of the evening. The President (Professor Dewar) spoke of his services to chemistry in glowing terms. A seniority of four months in Fellowship of the Society made Professor Odling's turn to speak precede Williamson's, who was in years considerably his elder, and Odling made happy use of the opportunity to refer to his brother guest. He said, "I have always looked upon myself . . . . as a follower of Williamson. It has been my pride to reckon myself one of his adopted pupils—a disciple of his ideas more perhaps than many of those who were his actual pupils. He was always very decided in his notions. Sometimes, indeed, I turned a little restive, but was always soon pulled up into form again—sometimes more abruptly, perhaps, than was quite agreeable at the moment. At one time I laboured under the sad suspicion of being a little unsound as to the Atomic Theory."

In 1901 Williamson gave up his office of Gas Referee under the Board of Trade, his health having then utterly broken down. He died in May, 1904, eighty years old, and was buried at Brookwood, in Surrey. Besides his widow, closely associated with him for half a century in almost every incident of his public and private life, with its many hospitalities, his daughter, Mrs. Fison, and her three children, and his son, Dr. Oliver Key Williamson, survive him.

Williamson was Ph.D. (Giessen); LL.D (Dublin and Edinburgh); D.C.L. (Durham); Hon. F.R.S.E.; Fellow of the University of London; Hon. M.R.I.A.; Hon. Member of the Literary and Philosophical Society of Manchester; Hon. Member of the German and American Chemical Societies; Corresponding Member of the French Institute (Academy of Sciences); Corresponding Member of the Royal Turin Academy of Sciences; Extraordinary Member of the Accademia dei Lincei, Rome; Extraordinary Member of the Royal Berlin Academy of Sciences. He was a Member of the Athenæum Club, elected by the Committee without ballot.

To know Williamson was to love him for his truly affectionate disposition. He was a true and constant friend. But there were many acquainted with him who never got to know him. There was a reserve about him which seemed to turn away advances and which made him appear indifferent to forming new friendships. This reserve, however, was all unreal and its appearance wide of the truth. His manner was largely attributable to his near-sightedness, which, firstly, in his youth led him to find his own company sufficient, and which, secondly, interfered always with that ready recognition of persons and faces which is necessary for the full enjoyment of social life. Far from being really reserved, he had an open and most sympathetic disposition. But, again, to his cost, he was an outspoken, severe, and caustic critic of doctrinal views in chemistry, and in this capacity he seemed to repel men of softer mould. It was always the doctrine he was hard upon, never the man who, to him, was foolish enough to hold it. Of no one was he a keener critic than of himself, and it was at times disconcerting to his followers to hear him dilate upon the weakness and uncertainty attaching to views which he was himself habitually defending. To some he seemed not to brook contradiction. It was not really so; he was only the strenuous advocate, and, however discomposed he felt for the moment, he gave and received blows without any trace of personal ill-will.

E. D.

SIR WILLIAM JAMES LLOYD WHARTON, 1843—1905.

William James Lloyd Wharton, second son of Mr. Robert Wharton, County Court Judge of York, was born in London on March 2, 1843. In August, 1857, having been previously educated at Burney's Academy, Gosport, he entered the Royal Navy on board H.M.S. "Illustrious," at that time recently commissioned as a training ship for Naval Cadets, stationed at Portsmouth. Passing out of the "Illustrious" with great credit, he was appointed midshipman of H.M.S. "Euryalus" in April, 1858, on board which ship Prince Alfred, afterwards Duke of Edinburgh, was also serving. In November, 1860, he was appointed to H.M.S. "Jason," and, while serving in her on the North American and West Indies Station during the summer of 1861, he was lent to H.M.S. "St. George," employed on fishery duties in Newfoundland. Having completed his time as midshipman, on January 13, 1863, he passed his examination in seamanship for the rank of lieutenant. The "Jason" returned to England to pay off at the close of 1864, Wharton having received his commission as Acting Lieutenant of her two months previously. He now had the opportunity of completing the necessary qualifying examinations in gunnery and navigation, in which he acquitted himself brilliantly, and was confirmed in his rank March 15, 1865. In December he was awarded the Beaufort Testimonial for passing the best examination of the year in Mathematics, Nautical Astronomy, and Navigation.

In the meantime, in July, 1865, he had been appointed to H.M.S. "Gannet," a sloop commissioned partly for the general duties of the fleet and partly for surveying service on the North American and West Indies Station, but acting entirely under the orders of the Commander-in-Chief. In that ship he acquired his first experience in the work to which his life was afterwards devoted, showing great ability and aptitude for surveying duties, and receiving the commendation of the Board of Admiralty for the zeal displayed by him in the work performed in the Bay of Fundy. The "Gannet" paid off in November, 1868.

The Commander-in-Chief, Vice-Admiral Sir James Hope, had already realised Wharton's abilities, shown as much by his practical work on board the "Gannet" as in the distinction he had gained in passing his examinations; consequently, when the Admiral was about to hoist his flag at Portsmouth, Wharton was offered the appointment of Flag-Lieutenant. The Hydrographer meanwhile had promised to submit his name as 2nd Lieutenant of H.M. Surveying Vessel, "Newport," and Wharton, considering himself pledged to the surveying service, was prepared to forego Sir James Hope's offer, although he was fully aware he would thereby sacrifice the prospect of certain promotion at the end of three years. Fortunately, however, Sir James Hope took another view, and, speedily arranging matters with the Hydrographer, Wharton was appointed as his Flag-Lieutenant on March 1, 1869. Whilst so employed he wrote "The History of H.M.S. 'Victory,'" which still commands a steady sale to the public, the proceeds being devoted to the Royal Naval Seamen's and Marine Orphans' Home, Portsmouth.

H.M.S. "Urgent" being temporarily commissioned in November, 1870, to convey a scientific expedition to the neighbourhood of Gibraltar to observe the forthcoming total eclipse of the sun, Lieutenant Wharton was gratified at being appointed to her as 1st Lieutenant for the cruise.

On March 2, 1872, he was promoted to Commander on Sir James Hope striking his flag, and the following month was appointed to the command of H.M. Surveying Vessel, "Shearwater," on the Mediterranean Station, and afterwards on the East Coast of Africa. His work in the Mediterranean was chiefly distinguished by a valuable contribution to Science in the form of an investigation of the surface and undercurrent in the Bosphorus, setting at rest the many controversies respecting the exhaustless flow of water from the Black Sea to the Sea of Marmora by proving that an undercurrent existed as strong as that on the surface, but which invariably flowed in exactly an opposite direction.

His report, which was officially published, may be considered as prescribing the method for similar enquiries.

Whilst at Rodriquez, in the South Indian Ocean, he took part in observing the transit of Venus in 1874.

The "Shearwater" was paid off in July, 1875, and in June the following year he commissioned the "Fawn" for surveying service in the Mediterranean, Red Sea, and East Coast of Africa. Starting with a staff of officers, most of whom were wholly inexperienced, Commander Wharton set himself to train them after his own ideals, and succeeded in imbuing his assistants with something of his untiring energy and love of the work. Whilst exacting the utmost that each individual was capable of giving to the service, he exercised unremitting patience and forbearance, and, throughout a prolonged commission of four and a-half years, endeared himself to all who had the happiness to serve under him. He was sympathetic and considerate towards both officers and men, and entered heartily into all schemes for their recreation when opportunity offered. This commission of the "Fawn" was perhaps one of the most successful, as it certainly was one of the happiest, ever spent by a surveying vessel in modern times. The last two years were occupied with the survey of the Sea of Marmora, an excellent piece of work for which he and his officers received an expression of the approbation of the Lords of the Admiralty.

On January 29, 1880, Wharton was promoted to Captain, and the "Fawn" was paid off at Malta at the end of the year.

"Hydrographical Surveying" was written by Captain Wharton during the interval of leisure which now followed, and immediately on its publication it was recognised as the standard work on the subject. As such it is still in use in both British and Foreign navies, its value being thus well proved despite the characteristically modest tone of its author's preface.

In March, 1882, Captain Wharton commissioned H.M.S. "Sylvia," for surveying service in the River Plate and Straits of Magellan. He successfully observed the transit of Venus for the second time in December that year. The work in the Straits of Magellan was pushed on rapidly in spite of hardships and difficulties which had to be encountered, with the result that the survey was completed within the allotted time, but two seasons' work carried on in such an inhospitable climate, and in such dangerous waters as the western part of the Straits of Magellan, told so considerably upon Captain Wharton, that during this time he aged much in appearance. Before he left England it had been an open secret that on the retirement of Sir Frederick Evans, Captain Wharton should succeed him as Hydrographer of the Navy.

On the return of the "Sylvia" to Montevideo in March, 1884, it became necessary therefore that he should leave the ship and proceed to England by mail steamer. On August 1, 1884, he was appointed Hydrographer, at an age younger than that of any officer preceding him in the office. This closed his career afloat.

Wharton's administration of the hydrographic department of the Admiralty continued uninterruptedly for 20 years with constantly increasing credit, and to the great advantage of our own Navy, as well as of the whole maritime world. This period covered the enormous expansion that took place both in the *personnel* and *matériel* of the Fleet, causing corresponding accessions to the labour of departmental work. During the same period the number of chart-plates was largely increased, and the number of charts printed annually for the Fleet and for sale to the public multiplied threefold.

Gifted with an extraordinary capacity for work, Wharton never spared himself; the sound judgment, and wide scientific attainments, which he constantly brought to bear upon the infinite variety of subjects with which he was daily called upon to deal, secured for him the respect and confidence of successive Boards of Admiralty, to whom he was an ever true and inestimable adviser in all matters hydrographic.

Not the least important part of his work at the Admiralty was the advice he was called upon to give on naval engineering works generally, and particularly on the great engineering schemes which have been proceeding during the last ten years under the Naval Works Acts.

In dealing with such questions, his clearness of thought, the breadth of his general knowledge, his keen appreciation of engineering difficulties, and his broad and far-seeing view of Naval requirements were of the utmost value in framing the general lines of the schemes, as well as maturing their details. Always willing to give his advice and assistance to his colleagues at the Admiralty, his general remarks and criticisms afforded information of the greatest value to them, and in general conversation on professional subjects all those with whom he was brought in contact could realise how wide his knowledge was.

The part he played in settling the main principles upon which the Naval Defences of the country are now based can only be known to and appreciated by those with whom he was associated at the time.

It was one of his marked characteristics that the mass of information he had acquired on all sorts of subjects was at once available on the spur of the moment. No matter what difficult question might arise in any part of the world, he was ever ready with the proper answer ; yet although his mind was such a storehouse of valuable and instantly available knowledge, he remained to the last the same simple and modest sailor as he began.

As ex-officio member of the Meteorological Council he attended its meetings assiduously and rendered important service to the advancement of Ocean Meteorology.

His personal interest in the surveying service was unceasingly manifested in the voluminous semi-official correspondence he maintained with the officers in command of surveys. Scientific subjects of every kind bearing on hydrography always claimed his attention. His strong desire was ever to make his work thoroughly scientific, and to ensure that the same ideal was kept before the surveying officers of the Navy. Thus he took great pains to have a new and revised edition of the 'Admiralty Manual' prepared, and he sought as coadjutors in this task the most distinguished and experienced men of science in each branch of investigation treated of in that excellent work. So anxious was he to furnish the surveying staff with all the available assistance in their work that he applied to the Director-General of the Geological Survey for a list of the more typical and frequently recurring minerals and rocks, and he had a series of collections of specimens made and distributed among the surveying vessels. He wished that every naval officer, besides being thoroughly trained to do the official work entrusted to him, should be taught to use his eyes in observing Nature, and be encouraged to communicate his observations to headquarters. Nowhere could these communications be more sure of a kindly and sympathetic reception than at the hands of the Hydrographer. He used to write appreciative letters to the authors of them, and where the observations seemed to be of sufficient novelty and importance he spared no pains to have them published either by the Admiralty or in the pages of some scientific journal.

In 1886 Captain Wharton was elected a Fellow of the Royal Society, serving on its Council from 1888 to 1889, again from 1895 to 1897, and lastly from 1904 until his death.

As a Fellow of the Royal Astronomical Society, as well as of the Royal Geographical Society, of which he was Vice-President, and as member of numerous committees, he rendered services only less important than his official work at the Admiralty. His first contribution to the publications of the Royal Society was the investigation of the great waves produced by the eruptions of Krakatoa in 1882, which had been begun by the late Sir Frederick Evans and left unfinished at his death. In 1893 he edited the journal of Captain Cook during his first voyage round the world. At the meeting of the British Association at Oxford in 1894, he presided over Section E. Many contributions to 'Nature' appeared from time to time from his pen, the investigation of the origin and formation of coral reefs being a subject of especial interest to him. On this question he advanced a theory, based upon the result of the surveys of a large number of these reefs, that the effect of wave action was mainly accountable for the striking uniformity of depth so frequently met with over the interior of coral banks in the open ocean. He insisted that the erosive influence of the waves in open oceans extends to greater depths than had previously been considered possible.

As a member of the Coral Reef Committee of the Royal Society, he was largely responsible for the selection of Funafuti as the atoll to be investigated by sounding and boring operations, and he was instrumental in securing the co-operation of the Admiralty in the work, which has produced such valuable results in the monograph published by the Royal Society. He was keenly interested in the project for Antarctic exploration, but more particularly in its bearing upon terrestrial magnetism, and he took an active part as a member of the Joint Committee of the Royal and Royal Geographical Societies appointed to organise it.

He was placed on the retired list in 1891, in accordance with the regulation respecting non-service at sea. Promoted to Rear-Admiral on January 1, 1895, on the Queen's birthday that year he was nominated as C.B. On the occasion of the Diamond Jubilee in 1897 he was created K.C.B.

On July 31, 1904, Sir William Wharton resigned the office of Hydrographer. For some years previously he had suffered much inconvenience and pain owing to an injury to his right wrist received whilst serving in the "Shearwater"; for this and other causes he determined to relinquish the appointment. In July, 1905, after a visit to Aix-les-Bains, he accepted with some hesitation the reiterated invitation to go out to South Africa with a party of members of the British Association, and he presided over Section E at Cape Town. Unfortunately he fell ill on the return journey from the Victoria Falls, and could not return to England, as he intended, with his friends. His illness, which was at first thought to be a chill, proved to be enteric fever complicated with pneumonia, and although no effort was spared to effect his recovery he died at the Observatory at Cape

Town on September 29, where he was the guest of his old and valued friends Sir David and Lady Gill. He was buried at the Naval Cemetery at Simon's Town on October 1, with naval honours, H.M. the King being represented by the Commander-in-Chief of the station. He was married in 1880, to Lucy Georgina, daughter of Mr. Edward Holland, of Dumbledon, in Gloucestershire, and by her, who survives him, he had two daughters and three sons, two of whom are now serving in H.M. Navy.

A. M. F.

SIR CHARLES WILLIAM WILSON. 1836—1905.

Charles William Wilson, second son of Edward Wilson, Esq., J.P., of Hean Castle, Pembrokeshire, was born in Liverpool, March 14, 1836. He received his education, first at St. Davids, and later at the Liverpool Collegiate Institution, at Cheltenham College, and the University of Bonn. In his nineteenth year he entered the Royal Engineers, gaining second place in the open competition and was gazetted Second Lieutenant, September 24, 1855.

His special fitness for pioneer work was early recognised, and in 1858 he was selected to serve as Secretary and Superintendent of transport and commissariat arrangements to the Commission for the Survey of the boundary between Canada and the United States. By the Treaty of 1846, the parallel of 49° N. had been constituted as the boundary line, but the earlier surveys made from the Atlantic coast had only been carried as far west as the meridian of 95° W., ending at the Lake of the Woods, close to the western extremity of the Province of Ontario. The survey party of 1858, under the command of Colonel Hawkins, the Chief Commissioner, began their operations at Boundary Bay, on the Strait of Georgia, and worked eastward through the difficult and uncivilised region of swamps, forest, and mountain, as far as the meridian of 114°, ending at the eastern boundary of British Columbia, on the eastern range of the Rocky Mountains. In the latter part of the work much of the superintendence of the actual survey was committed to Lieutenant Wilson, and on the completion of the survey in 1863 he received the thanks of the Secretary of State for Foreign Affairs, and was promoted to the rank of Second Captain.

In August, 1864, Captain Wilson undertook the task of making a survey of Jerusalem and the surrounding country, in connection with the scheme originated by Miss Burdett Coutts for providing a supply of pure water to that city. This work he accomplished with signal success, and he carried his survey through the country to the east of Jerusalem, as far as the Dead Sea, of which he determined the level. Owing to local intrigues, the project of the water-supply was not then proceeded with, but the maps and plans made by him are of permanent value and have been the groundwork of all subsequent topographical research in this region. He published descriptive notes explanatory of his maps at the time, and at a later date he wrote a short paper on the water-supply of Jerusalem.

The interest aroused by the researches of Captain Wilson, as well as his direct personal influence, led to the organisation, in 1865, of the Palestine Exploration Fund, and the Executive Committee of that body appointed him as the first Director of the Exploration. In this capacity he returned to Palestine in 1865, and made a preliminary survey of a large part both of Judæa and Galilee. He made plans and drawings of many ancient sites and ruins, and carried a line of Azimuths from Banias to Jerusalem. From this work he was recalled to take part in the Ordnance Survey of Scotland in 1866, and was succeeded by Captain (now Sir Charles) Warren. In recognition of the value of his survey he was elected member of the Executive Committee of the Palestine Exploration Fund, and later he was awarded the Diploma of the International Geographical Congress at Antwerp, in 1871. While connected with the Scottish Survey he acted as Assistant Commissioner on the Borough Boundaries Commission in 1867.

In 1868 he again visited the East to make, in conjunction with Captain Palmer, a survey of the Sinaitic peninsula, a difficult task which he accomplished in less than six months. His notes of this exploration were published in the following year. On his return he was appointed Executive Officer in the Topographical Department of the War Office, and in 1871, on the expansion of this branch into the Intelligence Department, he became its Director, with the rank of Assistant Quartermaster General. He was in this year elected Member of Council of the Royal Geographical and of the Biblical Archæology Societies, and in 1872 received the decoration of C.B. (Civil). In the following year he was promoted Major of Royal Engineers.

He was elected a Fellow of the Royal Society in 1874, and in that year was President of the Section of Geography of the British Association.

The next task entrusted to him was the compilation of the map of Afghanistan for the India Office. For this work, which he completed in 1875, he received the thanks of the Secretary of State for India. In the following year he was appointed to the Command of the Ordnance Survey of Ireland, in succession to Lieutenant-Colonel Wilkinson, and held that office until 1879. During his tenure of this office he also served on the Royal Commission for the Registration of Deeds and Insurances, and while in residence at Mountjoy Barracks he was a frequent and welcome guest at the Council breakfasts of the Royal Zoological Society, and took much interest in the work of that Society.

In 1878 he was again ordered abroad to serve as British Commissioner for the delimitation of the boundaries of Servia under the Treaty of Berlin. For his services in that capacity he received the thanks of the Government, and was promoted Brevet Lieutenant-Colonel in 1879.

On account of his remarkable knowledge of Eastern affairs he was appointed in 1879 to the responsible post of Consul-General in Anatolia. While he held this office he travelled through little-known parts of Asia Minor, and was sent on special missions to Bulgaria, Macedonia, and Roumelia. Much of the information which he thus collected is embodied in the "Handbook to Asia Minor" and the "Handbook to Constantinople," edited by him for Murray's Series. For these services to the Foreign Office he was accorded special thanks, and he received the Order K.C.M.G. in 1881. In that year he was also promoted Regimental Lieutenant-Colonel.

On the outbreak of the rebellion of Arabi Pasha in 1882 he accompanied the force under Sir Garnet Wolseley to Egypt, and took his share in active military service. On the suppression of the insurrection he served under Sir Edward Malet, and was put in charge of several important matters; among others he was appointed to superintend the prisons in which the political prisoners were confined, and to watch their trial, on behalf of the British Government. In the discharge of these duties there were many difficulties to be overcome, but these he surmounted with much tact and discretion, and received the thanks of the Government and the rank of Brevet-Colonel in 1883.

When Lord Dufferin's Commission was sent for the reorganisation of the Egyptian Administration, Colonel Wilson was appointed on the Staff, and in this capacity his attention was directed to the affairs of the Soudan, where the Mahdi Mohammed Ahmed had proclaimed himself as the prophet foretold by Mohammed and had raised the standard of rebellion against the Egyptian Government in August, 1881. On this subject Colonel Wilson made a report in 1882 to the Consul-General, and recommended that a British force should be sent to Khartoum to examine and report on the steps which were required for the quieting of the native unrest. In accordance with the suggestion in this report, Colonel Stewart was sent thither and made his report in 1883, but the recommendations made therein were shelved, although by that time the rebellion had become a formidable menace to Egypt after the crushing defeat of Assuf Pasha. Meantime Sir Charles Wilson was recalled home to his former post as Director of the Irish Ordnance Survey. The British Government imperfectly realised the gravity of the situation, and sent, in 1884, General Gordon for the purpose of withdrawing the isolated garrisons of Egyptian troops from the Soudan. The subsequent events are matters of history, and need not here be detailed. When the Government realised the necessity of sending an expedition for the relief of Gordon, Sir C. Wilson was appointed Chief of the Intelligence Department with Lord Wolseley's force, and joined the Army in September, 1884, with the rank of Deputy Adjutant and Quartermaster-General. The expedition reached Korti, south-east of Dongola, on December 16, 1884, and on January 8 Sir Herbert Stewart and Sir Charles Wilson were sent on with the Camel Corps to communicate with Gordon, and to let him know that a relief expedition was on the way. The instructions were explicit that Wilson was only to stay long enough to confer with General Gordon and to return then at once with Lord Charles Beresford to Matammeh. In his book on the expedition "From Korti to Khartum" (1886), Sir Charles Wilson has given a graphic account of this disastrous journey and of the chapter of accidents which delayed it. As Sir Herbert Stewart was wounded at Abu Klea the command devolved upon Sir Charles Wilson, and he started from Gubat at the earliest possible opportunity, on the 24th January, for his four days' journey up the Nile, only to learn that Gordon had been killed on the 26th. Even had he arrived two days earlier with the small and undisciplined force under his command, he would have been unable to alter the course of events, and would most probably have shared Gordon's fate.

For his services in this expedition he received from the Secretary for War a telegram of "warm recognition of Government of brilliant services of Sir Charles Wilson, and satisfaction at gallant rescue of his party." He was specially mentioned in Lord Wolseley's despatches, and was created K.C.B. in 1885.

Shortly after his return home he was appointed Director-General of the Ordnance Survey, and began the revision of the Irish Survey maps on the 1/2500 scale, as well as the Survey of Yorkshire and Lancashire on the same scale. He also carried on a general revision of the small scale maps, so as to bring them up to date. He initiated a scheme for the organisation of Survey sections for service with an army in the field. He continued in command of the Survey until 1894, having been promoted Major-General on February 15 in that year. In the next year he was appointed Director-General of Military Education, an office which he held until 1898, when he retired under the age clause of the Royal Warrant. While discharging these duties he found time to write a "Life of Lord Clive," for the "English Men of Action" series published in 1890. Sir Charles Wilson served on the Council of the Royal Society, 1889–90, and his work was recognised by the conferring on him by Oxford of the honorary degree of D.C.L. in 1883, by Edinburgh of the degree of LL.D. in 1886, and by Dublin of the degree M.E. in 1893.

Through all the stages of his varied career he kept up his interest in the work of the Palestine Exploration Fund, and on the retirement of Mr. Glaisher he was unanimously elected Chairman of its Executive Committee. The duties of this office he discharged with unremitting zeal, keeping himself in touch with the progress of the work of exploration in the field, visiting the excavations both at Tell Zâkariyeh and later at Gezer. For the last year of his life his work was hindered by a severe affection of the eyes, but he continued to edit the "Quarterly Statement" of the Fund and to attend its committee meetings almost to the end. The last research on which he was engaged was an exhaustive study of the evidence as to the site of the Holy Sepulchre, and he had almost finished the revision of his manuscript when he was laid aside by his last illness. This book will soon be published by the Palestine Exploration Fund under the supervision of Sir Charles Watson, who has succeeded him as Chairman of the Executive Committee of the Fund. He died on October 25, 1905, at Tunbridge Wells.

Sir Charles Wilson married, in 1867, Olivia, daughter of Colonel Adam Duffin, Bengal Cavalry, who survives him ; he also leaves a daughter and four sons, three of whom are officers in the Army.

He was in manner quiet, courteous, dignified, and remarkably unobtrusive, but one could not be long in his company without realising his quick and correct judgment of men and affairs, his wisdom and firmness of purpose, his kindness and consideration for others, and his extraordinary store of accurate knowledge. Those associated with him on the Committee of the Palestine Fund learned to rely implicitly on his advice, and willingly to accept his decisions as final. They feel that they have lost a wise and judicious friend indeed, and have stated in their last published report that his death is "the severest personal loss that the Fund has ever sustained."

In addition to the published works referred to, Sir Charles Wilson was also the author of: 1. "The Recovery of Jerusalem," 1871. 2. "Jerusalem the Holy City," 1889. 3. "Picturesque Palestine, Sinai and Egypt," 4 vols. 1880. 4. "The Pilgrimage of the Russian Abbot, Daniel," 1895.

The writer is deeply indebted to Sir Charles Watson for much of the information embodied in this biographical notice.

A. M.

OTTO STRUVE. 1819—1905.

The death of Otto Struve on April 14, 1905, closes more than one chapter in the history of Astronomy. One such chapter might be headed "The Pulkowa Observatory," and we should find Otto Struve's name on almost every page from the first to the last. At the foundation of the Observatory in 1839, he went as assistant to his famous father; within a very few years he began to perform some of the Director's duties, and long before he officially succeeded his father in 1864 he had been practically the head of the Observatory. When at last he left Pulkowa after 50 years spent in its service, the "Pulkowa Observatory" officially ceased to exist* and became the "Observatoire Central Nicolas."

Changing our historical arrangement a little, and classifying by lines of investigation rather than by localities, there is a great chapter on "Double Stars" written by the two Struves, following that written by the Herschels. Otto's name does not occur here till nearly the middle of the chapter; unless perhaps we find room on the first page, when mentioning the publication of W. Struve's first Catalogue of 727 stars in 1820, to record the recent birth of the son who was to be so worthy an assistant and successor.

Once again, regarding not the doings of a single observatory or the history of one branch of astronomy, but taking a more general outlook on the spirit of the times, we realize that in Otto Struve there passed away a commanding figure of the "old school" of astronomers. An attempt to define too closely the characteristics of this school would inevitably result in error and failure: but it is significant that the fourteen volumes of observations published under Otto Struve's Directorate all relate to the *positions* of stars, and contain no allusion to the spectroscope or the photographic plate. Nevertheless (and there could not be a better illustration of the dangers of being too definite) we must at the same time remember that the very existence of the department of Astrophysics at Pulkowa is due to him, and that he only established it after considerable trouble. Struve began work at a time when it was scarcely dreamed that Astronomers would ever use the spectroscope or take photographs, and his first lessons were calculated to impress indelibly upon his mind the fundamental importance of work in which the spectroscope and the photographic plate have even yet taken no part. His early years were devoted to a determination of the constant of precession, and the value he obtained was adopted for general use. His observations led him to side with Herschel, and against Bessel, on the question (at that time new) whether the Solar system was moving in space. Moreover, he witnessed the determination, about the same time, of the constant of aberration by his father, and of that of nutation by his colleague Peters. He saw the Pulkowa Observatory take a leading place in the astronomical world for its accurate measures of stellar positions, and it was his own life work to help in raising it to that place and maintaining it there. He lived long enough to see a new constant of precession suggested for adoption, after his own had been in use for half a century, and died just as evidence* was being published in support of his old value as against the proposed change.

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* The description of the Observatory published by F. G. W. Struve in 1845 is entitled 'Description de l'observatoire astronomique Central de Poulkova.' Fourteen volumes of observations were published by Otto Struve, entitled 'Observations de Poulkova, publiées par Otto Struve, Directeur de l'observatoire Central Nicolas,' the last words being in quite small type. On Struve's retirement a new series of volumes was started with the style 'Publications de l'observatoire Central Nicolas, Série II.' The last volume of Série I to appear, numbered vol. 10, is dated 1893, and contains Struve's name as "Ancien directeur."

Otto Wilhelm Struve was born on May 7 (April 25, O.S.), 1819, at Dorpat, where his father was Professor in the University and Director of the Observatory. He was the third in a family of 18 children. He completed his gymnasium and university course early and was already an assistant to his father when the latter was summoned to found and direct the great Pulkowa Observatory. Otto took his place as assistant in the new Observatory with three colleagues, G. Fuss, G. Sabler, and C. A. F. Peters.

The programme adopted at the outset was the determination of three astronomical constants, aberration by W. Struve, nutation by Peters, and precession by O. Struve; and the success attained has already been mentioned. Other observations of an orderly kind were also carried on, but there was no attempt made to publish them for many years. This fact was lamented by Airy in 1847, and doubtless his representations had some weight in stimulating the ultimate publication of the first two volumes in 1869. But this was after the directorship had passed from the hands of W. Struve into those of his son. It seems proper to recall here, alongside the mention of Airy's action, that we owe to Otto Struve the movement for doing full justice to the observations made by a great Englishman. It was Winnecke, at Struve's instigation, who first undertook the re-reduction of Bradley's observations, though the work passed into the able hands of Dr. Auwers at an early stage.

For the determination of precession, which occupied his early years at Pulkowa, Otto Struve received the Gold Medal of the Royal Astronomical Society in 1850. The work had been completed nine years before, and this fact is apologetically mentioned by the President (Airy) in an interesting manner. "A rather unusual delay," he said, "has occurred in the notice of this paper (on precession). This has arisen partly from the delay which usually occurs in the printing and distribution of foreign memoirs, partly from the time which is necessary for thoroughly reading a paper of such length; but principally from the occupation of the minds of astronomers, as well within as without the Society, by the remarkable planetary discoveries made in several years past." This was in February, 1850, the discovery of Neptune having been made on September 23, 1846, while six new minor planets had just been found, after a barren interval of 40 years since the first four.

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* 'Mon. Not. R.A.S.,' vol. 45, p. 443. Dated March, 1905, published in April. Struve died April 15.

The mention of the discovery of Neptune recalls the fact that Otto Struve was elected an Associate of the Royal Astronomical Society on the same day (May 12, 1848) as Galle, who actually discovered the planet; and Struve's death leaves Galle as the unrivalled *doyen* of the Society, which honoured him a dozen years before any existing Fellow was elected.

But having completed his work on precession, Struve became henceforth a double star observer. We may no doubt trace this bent to his whole-hearted devotion to his father, which is writ large on every page of his published works. It was not in double star observing alone that this devotion found expression. In a memoir of his father left in MS. he has recorded that in 1845 (when he was only 26) he had already practically taken over the duties of administration of the Observatory, though the official acknowledgment of the fact did not follow for many years. Possibly the strain of these early years may have contributed to the serious illness which overtook him in 1864 soon after he was actually appointed Director. The doctors actually gave him up, and though he recovered, he was so broken in health as to think of resignation. A winter in Italy, however, fortunately restored him; and he returned to a long and prosperous term of office and activity. Indeed the length of his record as an actual observer is remarkable; there are certainly one or two measures of double stars recorded as made by him at Dorpat in 1836, and there are others dated 1889. Few indeed can match a record of 53 years as an observer.

But his veneration for his father fortunately did not cramp his originality. He selected for special study stars of a distinctly new type. W. Struve had deliberately chosen double stars with components not differing much in brightness; what first suggested to his son to form a catalogue of stars having faint companions? The difference may at first seem to be one of detail; but it represents an important step taken in the study of double stars, preparing the way for the modern work of Burnham and others.

Another important line struck out by Otto Struve for himself was the investigation of personal peculiarities of measurement. The idea of "personal equation" in a variety of forms is familiar enough to us now; but in 1853 it was only recognized in transit observations, and was deduced from comparison of the observations themselves, not by any attempt at independent determination. Such comparisons of observations *inter se* were, in the case of double star observations, not available in sufficient number to determine personal differences, though there were enough to suggest them. Struve devised his famous artificial adjustable double star to investigate his own peculiarities. The actual separation and position angle of the artificial double were known; and turning his telescope horizontally towards the distant model and measuring them as he would those of a real double, he found the systematic errors in his measures. The errors were large (13° in position angle in some cases) and were not quite satisfactorily determined with the apparatus, as is intelligible when we remember that the stars in the actual sky are observed with a telescope which is anything but horizontal, and that they are liable to atmospheric disturbances. But Struve obtained at any rate a large measure of success, and was able not only to eliminate the main part of such systematic errors from his future observations, but by comparison to infer suitable corrections for observations already made. The summary of his life-work as an observer is to be found in Volumes IX and X of the Pulkowa Observations, Volume X being completed in 1893.

We must not forget to add the work he did in editing, jointly with Schiaparelli, the two volumes of Dembowski's observations of double stars which appeared in 1883.

It would do scant justice to Otto Struve to regard him merely, or even chiefly, as a double star observer. The range of his interests and activities was very wide. In 1851 he read before the Academy of Sciences an elaborate paper on the Rings of Saturn, suggesting from a discussion of old and recent observations that they were spreading inwards to the planet; (this hypothesis has not been confirmed). Geodetic work absorbed much of his attention, and it was on his initiative that the 47th parallel of latitude, which had been selected for measurement, was given up in favour of the 52nd. By this change the arc was extended at both ends; the eastern end became Arsk in Siberia, and (what is of chief interest to us) at its western end the arc crossed England and terminated in Valencia in the extreme S.W. of Ireland. Recent work on the longitude of Waterville carried out under the direction of the Astronomer Royal has a direct bearing upon the investigation as modified by Otto Struve.

In another enterprise of international interest he was not so successful. He had succeeded in persuading the authorities of the advantages in adopting the Gregorian calendar in general use by other European nations; and the change was under serious consideration in high quarters, when all chance of reform was abruptly destroyed by the dynamite explosion in the Winter Palace.*

On the occasion of the Paris International Conference in 1887, which led to the scheme for charting the heavens by photography, Struve was unanimously called to the chair. His opening address contains a paragraph so characteristic of the man and of the epoch that it may fitly be quoted here.

"En effet, l'Astronomie pratique possède aujourd'hui, dans la Photographie, un instrument de la plus haute valeur et qui, probablement, avec le temps, facilitera énormément nos études épineuses. Mais restons sobres dans nos prévisions. Pour le moment, nous ne devons regarder la Photographie que comme un instrument très précieux, mais dont l'étude reste encore à compléter. Nous devons tâcher d'élever la Photographie céleste à ce degré de perfection qui la rendra digne de concourir sous tous les rapports avec les méthodes d'observation usitées jusqu'à présent, méthodes qui ont valu à l'Astronomie pratique la position enviable d'une science expérimentale dont les conclusions peuvent rivaliser en rigueur avec les théories mathématiques."

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* V.J.S. 'Ast. Ges.,' Jahrg. 40, Heft 4, pp. 298–9. To this notice by M. Nyrén the present writer is indebted for much of the information here given.

These words remind us of those in which Wilhelm Struve opens his description of the Pulkowa Observatory (1845):—"L'Astronomie, par la sublimité de son sujet, occupe une place éminente parmi les sciences naturelles. Elle est, par excellence, la science naturelle exacte."

It may be doubted whether Astronomy in its modern developments will be able to maintain this claim of an exactitude greater than that attainable in other sciences, if indeed it could ever rightly advance it; but there is no doubt that to the Struves the claim was a righteous one, and was the source of no little inspiration.

The Transit of Venus of 1874 brought with it much work of organisation for Otto Struve. So too did the Total Solar Eclipse of 1887. His own preparations for the latter event were characteristically all for observations of position, but some 40 astronomers of other nations visited Russia on the occasion, and Struve made the most hospitable arrangements and careful plans for their comfort. Nearly all of them passed through Pulkowa and were entertained by him at his own house. He took great interest in their proposed work, though much of it was clearly strange to him. For instance, he learned with obvious surprise of the time for preparation required by those desiring to make photographic or physical observations: he had estimated that no one would wish to be at his station more than 2 or 3 days altogether. But on realizing their requirements, he did all he could to secure the requisite facilities. The memory of those few days at Pulkowa, when at the same table, spread in the open air in order to make the most of the short northern summer, there were gathered astronomers from Italy, Spain, France, Germany, America, and England, to each of whom Otto Struve spoke in his own language; when we caught a glimpse of the daily life of the little secluded community, with such special features as the disappearance of all the males in the afternoon to sleep, so that they might be regularly on the alert for observations till 3 A.M.; when we were privileged at night to look through the great 30-inch refractor, which had not then been thrown into shade by the Lick and Yerkes telescopes;—the memory of these days will long remain with astronomers of many nations. They were almost the last days of Struve's life at the Observatory. Two years later, in 1889, there was again a great gathering of foreign astronomers to celebrate the Jubilee of the foundation of the Observatory: but Struve's resignation had already been accepted, although it had been decided, by the express wish of the Czar, that he should remain in office until the ceremony was completed.

Otto Struve was twice married: first to Emilie Dyrssen, who died in 1868; secondly, to Emma Jankowsky, who died in 1902. He celebrated the "silver-wedding" of both marriages. By his first wife he had several children, of whom 4 sons and 2 daughters reached maturity, though one died before her father; by the second wife he had one daughter. Of the sons the two youngest are well known astronomers: Hermann, Director of the Berlin Observatory, who received (in the third generation) the Gold Medal of the Royal Astronomical Society in 1903 for his brilliant work on the satellites of Saturn with the great Pulkowa refractors; and Ludwig, Director of the Charkow Observatory, who followed in his father's footsteps by determining the constant of precession and the movement of the solar system.

The honours conferred on Otto Struve would make a long list, for he was a foreign or corresponding member of almost all European learned societies. The date of his recognition by the Royal Society is 1873. In 1868 the Bonn University conferred a Doctorate upon him, *honoris causa.*

After his retirement from Pulkowa he lived a few years in St. Petersburg; later in Karlsruhe, on account of failing health; though until recently he paid a visit to St. Petersburg every summer. He died without any serious protracted illness, in his 86th year, on April 14, 1905. By his own wish his ashes are to be taken to Pulkowa and laid under the stone on which his own special instrument, the 15-inch refractor, stood at the time of his observations.

H. H. T.

GEORGE JAMES SNELUS, 1837—1906.

THE subject of this notice was born at Camden Town on June 25, 1837. He was originally trained as a teacher at St. John's College, Battersea, and subsequently, while following this profession, he attended lectures at Owens College, Manchester. It was here, under Professor Roscoe, that Mr. Snelus laid the foundation of his success by his study of Chemistry and Metallurgy. In 1864 he gained the first Royal Albert Scholarship, and consequently entered upon a three years' course at the Royal School of Mines. Here he succeeded in obtaining the Associateship in Metallurgy and Mining, and was awarded the De la Beche medal for mining. At the end of his course he was recommended by Dr. Percy for the post of chemist at Dowlais Works, and he remained there until 1871. In 1869 he was elected a Member of the Iron and Steel Institute, and the brilliant series of papers, representing a large amount of true pioneering work, read before that body in the early seventies will secure for him a lasting place in the annals of the iron and steel trade. He was elected a Member of the Council in 1881, and during the next twenty-five years no one attended the meetings more regularly or took a greater interest in the general development of that body. He became a Vice-President in 1889. In 1871 Mr. Snelus was selected by the Iron and Steel Institute to visit the United States, and report on the chemistry of the Dank's rotary puddling process, and the report, when completed, proved to be the most important contribution ever published on the scientific features of the puddling process.

Whilst at Dowlais Mr. Snelus made observations which led him to the conclusion that phosphorus could be removed from iron while the metal was in the molten state. Experiments showed him that lime could be burned at a high temperature so as to be impervious to water, and it occurred to him that if he used lime so over-burnt as a lining for a Bessemer converter he would get a basic lining which would not be acted upon by basic slag, and so would be able to eliminate the phosphorus during the Bessemer process. He took out a patent for this in 1872, and soon afterwards proved experimentally the correctness of his surmise. The invention, however, was not pushed forward or made a practical success in his hands, and it was not until the "basic process" had been developed by Messrs. Thomas and Gilchrist, with the assistance of Mr. E. P. Martin, Mr. E. W. Richards and his metallurgical staff, that it came into commercial operation. It is an undisputed fact that Mr. Snelus was the first to make steel in a lime-lined Bessemer converter.

For his invention in connection with the basic steel process Mr. Snelus was awarded a gold medal at the Paris Exhibition of 1878, and in 1883 the Iron and Steel Institute recognised the part he had played in developing the process by awarding him, jointly with Mr. Thomas, the Bessemer medal.

For his discovery, and for his numerous and valuable literary contributions connected with iron and steel, Mr. Snelus was made a Fellow of the Royal Society in 1887. During the period 1869—1885 he wrote and spoke on a great variety of matters connected with the manufacture of iron and steel, and he was really the first to bring to the notice of iron and steel works' chemists in this country the true practical value of the molybdate method of determining phosphorus in iron and steel. Indeed, it was mainly due to the influence of Mr. Snelus that chemists in steel works learnt to make analyses sufficiently rapidly to be of value in controlling the manufacture of steel.

He went to Cumberland in 1872 and took up the position of manager of the West Cumberland Iron and Steel Company, where he remained many years. Subsequently these works were discontinued and to a large extent dismantled. From that time Mr. Snelus did not undertake managerial work, although he was director of several companies engaged in the iron trade.

Only quite recently he had invented a new process for the manufacture of steel, by which a basic-lined rotary furnace is employed. Whether this new process will prove a success remains to be seen.

Much of his leisure time was devoted to Volunteering and rifle shooting. He served as a Volunteer for 32 years, and was, for many years, one of the best rifle shots in the country. He was for twelve years from 1866 a member of the English Twenty, and during that period gained a greater aggregate than any other member of the team. Mr. Snelus was also an enthusiastic horticulturalist and a staunch Conservative, and was keenly interested in local affairs, public bodies seeking eagerly for his services.

He married Miss L. W. Woodward, daughter of Mr. David Woodward, of Macclesfield, and had three sons and three daughters. Mrs. Snelus died in 1892. Mr. Snelus spent a busy life until his health broke down. After a long illness he died at Ennerdale Hall on June 18, 1906.

J. E. S.

CHARLES JASPER JOLY, 1864—1906.

Charles Jasper Joly was born in Tullamore, Ireland, on June 27, 1864. His father, the Rev. John Swift Joly, was a man of studious bent and author of archæological studies of local interest. It can hardly be said that any of the more nearly antecedent ancestors of Charles Jasper foreshadowed his remarkable gifts. The family is French on the father's side, having emigrated from France so long ago as the middle of the eighteenth century. If heredity is to be appealed to for Joly's mental powers, it is necessary to go back to the seventeenth century, when Claude Joly, an author of distinction, appeared among his ancestors, but not in the direct line. The family claims, however, direct descent from Jacques Joly, a Secretary of State (about 1640), and from Reginald, born 1375, who was "Conseiller" in 1420, as well as from Antoine Joly, of Blaisy-en-haut, a seigneurie in Burgundy, near Dijon, which was erected into a Marquisate in favour of the said Antoine.

Charles Jasper was a brilliant boy at Galway Grammar School, appearing able, when so inclined, to win whatever medals and prizes he aspired to, and even several at one time. In the public Intermediate Examinations he took prizes and honours, but although possessed of this amount of reputation when he entered Trinity College, Dublin, in his eighteenth year, the exceptional powers which he subsequently developed were not indicated in his school career. Even as a student in Trinity College there was nothing accomplished by Joly that has not been accomplished by many a man who subsequently remained without further distinctions through life. He took a mathematical scholarship—by no means on specially brilliant marks—and finally won a mathematical studentship, but, again, without the distinction of the "Large" gold medal. His second subject at this examination was Experimental Science.

After leaving Trinity College he went to Berlin and entered Helmholtz's Laboratory with the intention of making Experimental Physics his life study. There he worked under Koenig's supervision, and would, doubtless, have carried out his intention of giving himself up entirely to the fascination of Physical Research had not the death of his father recalled him to Ireland and rendered it necessary that he should seek some more sure road to a competency. That he altered his intention of devoting himself to Experimental Science was perhaps for the best. For, while he certainly never showed any exceptional originality in that direction, his after career fully justified his diversion to mathematics.

The possibility of attaining to the Fellowship of his own College induced him to pursue the mathematical and mathematical-physics courses required for the mathematical side of this test. The severity of this competition is intensified by the extraordinary arrangement permitting candidates in mathematics and classics to compete against each other; the successful candidate being the winner of highest marks, where subjects, papers, examiners are different. For this ordeal it is not uncommon for men to read for five or seven years; not, perhaps, acquiring fresh wisdom after the first two or three years' reading, though gradually becoming more proficient in the art of scoring.

Year after year Joly fell short of success. Year after year he read Dante and other masters of literature, and, led away by the facile charms of literary studies, he plunged, forgetful of everything else, into the real or unreal world of poetry and romance. It was at this period that my own more intimate friendship with him commenced. Besides the tie of relationship, we had many tastes in common. In the course of our endless discussions and speculations there was revealed to me a mind both keen, critical, and honest; a nature undemonstrative, sincere, and deeply affectionate.

It was not till 1894 that Joly was successful in his efforts to gain Fellowship. He appears to have attained something more than Scholarship by the long and arduous preparation required for this trying test. He was injured neither in freshness of originality nor in bodily health. He set to work almost immediately he became Fellow on mathematical work, the only holiday intervening being the annual Swiss tour.

A word must be said here on Joly as member of the Alpine Club. His development as mountaineer was as unexpected as his mental evolution. Delicate in appearance, pale in complexion and with rather stooped shoulders, no one would have predicted the athletic prowess he displayed. But two factors were in his favour: he possessed undaunted courage and a power of endurance which must have had its origin also in a marvellous nervous organisation. A very few years later I was with him in circumstances of considerable danger, when on the arête of the Eiger we made our way downwards in the midst of a furious snow storm. Joly led the way with a skill and nonchalance which even in the midst of our troubles claimed our attention. Later, climbing became a passion with him, and his holidays were passed in the Alps, ascending the most difficult peaks. The Dent Blanche, Kleine Zinne, and many others were ascended. (See notice by Dr. George Scriven, 'Journal of the Alpine Club,' February, 1906, vol. 23, p. 58.)

The first work to appear from his pen, "The Theory of Vector Functions," was read before the Royal Irish Academy in the same year in which he got his Fellowship. A second paper on the subject of Vector Linear Functions appeared in the ensuing year, 1895, and two others the next year.

At this period his marriage with Jessie, daughter of the late Robert Meade, took place.

Later in the year 1897 the Board of Trinity College appointed him to the Andrews Professorship of Astronomy and to the post of Royal Astronomer of Ireland. The appointment was a particularly happy one, although at the time there was some difference of opinion as to his suitability for the office. But not only had Joly considerable training in manipulative scientific work, he was already recognised as highly accomplished in the Mathematics of Hamilton, and possessed of originality and activity. All through his reading for the Fellowship he had been more and more drawn to the use of Sir William Rowan Hamilton's mathematical methods, and it was even stated at the time that his examiners had themselves some difficulty in following the young mathematician in his facile use of Quaternions.

The election accomplished, Joly took up his abode in the historic house of Dunsink, wherein Brinkley, Hamilton, and Ball had done much of their best work. Joly now had the freedom from the too constant invasion of visitors and friends and the quiet and healthful surroundings favourable to mental activity. Never, indeed, had the life of a recluse any charm for him. He associated himself with some of the most important Institutions of the City of Dublin and never failed the committee which had a claim upon him. But he was spared petty interruptions. His teaching duties as Professor of Astronomy were light—one Term in the Session—and an able and careful Assistant was at hand to do the bulk of observational work. The mornings were generally free from disturbance, and, as will be seen, an amazing amount of work was done during the next few years of this quiet life.

Many who read this brief memoir will know the beautiful precincts in which Joly and his predecessors have done such good work. The old House commands from the south windows an extensive view. The panorama of the Dublin Hills—the rounded granite hills of Leinster—rising one beyond the other, invite the imagination into the furthest distance. Between lies a broad and noble valley containing in the near distance the lawns and woods of Phœnix Park, and to the east the City of Dublin. The pastoral element predominates, however, and, seen from this view-point, Dublin might appear to be a city girt with peaceful lawns and forest trees. Further yet, beyond the "towers, domes, citadels," the Bay of Dublin stretches to the horizon. A more varied sweep of mountains, forest, city and sea it would be hard to find. From the south window of the study an observer lifting his eyes can, at a glance, review it all. Around the house is the fruit garden and shrubbery, planted by Brinkley and Ball, and the old-fashioned box-trimmed flower garden merging into the orchard. Tall trees line the shady walk leading to the gate in the wall where suddenly is revealed to you, across steeply sloping fields, the same majestic panorama of mountains and woods seen from the study window.

In this home Joly lived to the end of his brief life, its quietness and its beauty contributing to his work and to his happiness.

A period of ever-increasing mental activity followed upon his appointment. The great work of editing 'Hamilton's Elements of Quaternions' and bringing this vast treatise up to date was already upon his hands. It had now to be completed, but its completion did not hinder Joly from continuing the publication of papers on various mathematical subjects. Thus we have a paper on "The Associative Algebra Applicable to Hyper-space" in 1897; one on the Congruency of Curves in 1899; and still others in 1900 and 1901. In 1900 he accompanied the Eclipse Expedition sent out by the Royal Dublin Society and the Royal Irish Academy, to Spain, and obtained some exquisite photographs of totality.

In 1899 the first volume and in 1901 the second volume of the new edition of Hamilton's Elements appeared. What the editorial work involved in patient and brilliant scholarship will only be appreciated by those acquainted with the vast and difficult literature which had to be analysed and embodied in the new edition. About 150 quarto pages of new matter were added.

During the couple of years succeeding this editorial work Joly was mainly occupied in extending his reading in Astronomical Science. Two other papers on mathematical subjects, however, appeared during this interval, and the laborious work of editing a new edition of Preston's 'Treatise on Light' was accomplished.

In December, 1902, Joly's paper on "Quaternions and Projective Geometry" was communicated to the Royal Society by Sir Robert Ball and appeared in the 'Transactions.' We ourselves know that the writer regarded this as a great advance and as a hopeful extension of the utility of Quaternions to new fields of investigation. His name was put up for Fellowship in the Royal Society in 1904 and his election followed the same year.

In the year 1905 the Manual of Quaternions appeared. I have omitted reference to various mathematical papers which preceded this work. The Manual appeared in the centenary year of Hamilton's birth. The work was written in a marvellously short space of time—about a twelvemonth. He however, wrote mathematics, worked out examples, and pursued his reasoning with the facility and ease with which a ready writer of fiction might develop the events of a novel. This, about his last great work, was received with commendation on every side; a reception all the more flattering as those who were admirers of Tait's treatment of the subject had to adapt themselves to a somewhat different mode of development before they could appreciate the new writer's work. Indeed, the Hamiltonian method of establishing the laws of Quaternions is here in part abandoned. In this work the author makes use of a wonderfully extensive knowledge of the mathematics of every branch of Physical Science.

In 1905 he took part in the visit of the British Association to South Africa. It was shortly after his return that first his little daughter and then he himself contracted the illness (typhoid) which, after a protracted period of many weeks, during which his strength was slowly sapped, gave rise to a complication (pleurisy) against which he could no longer contend. To the last moment of consciousness he showed the same unselfish consideration for others which was one of his most lovable characteristics. At a little after midnight—early on January 4, 1906—he passed away unconsciously.

In the last year of his life he acted as secretary to a Committee appointed by the Board of Trinity College to enquire into the mode of election to

Fellowship in Trinity College. A serious constitutional evil is undoubtedly existent in the exclusively examinational nature of this mode of selection. Joly never mentioned this matter without disapproval, and the Committee was appointed largely at his request. He gave much time and thought to its work, but the recommendations of the Committee led to no remedial measures. The appointment of a Government Commission, to which he had often looked forward as probably the only hope of drastic reform of this and other constitutional evils, took place a very few months after his death. It would be hard to estimate how much of the time and thought of distinguished Trinity men have been absorbed upon this hitherto fruitless subject of contemplation. It must be remembered that the constitution of their University regulated the lives and surroundings of these men. Every feeling of loyalty to their University as well as every disinterested desire to benefit the higher education of their country, acted to urge into action men of the stamp of FitzGerald and Joly.

His extraordinary powers of mathematical head-work are known to his more intimate associates. The problem stated, Joly's blue eyes sparkled with an expression which might more readily be taken for mirth than for abstraction. A characteristic gesticulation in these moments of thought was the stroking of his short beard. In an astonishingly short time the solution often came—perhaps more than one—and not till then was pen and paper resorted to that the enquirer might have it put before him. Men of very considerable mathematical training who had sought in vain for the solution and got it in this way were naturally impressed. There was undoubtedly a comprehensiveness in his learning which has rarely been excelled even by the greatest of mathematicians, and it must be remembered that almost his entire work was accomplished within the short space of 10 years; far the greater part within the last five years of his life. This rapidity of production indicated both thoroughness of knowledge and swiftness and sureness of reasoning. The remarkable powers of head-work were but the expression of these accomplishments and gifts. He possessed, in common with FitzGerald, a wonderful power of abstraction from immediate surroundings. Much of his work was done while conversation was going on around him. Joly generally reclined on a sofa when writing. The paper was held on his knee. The actual work was done in this attitude. A final copy was then typed.

He wrote a clear and simple style of English, without effort or affectation. Most of his letters might be sent to press without a word of alteration. Full of point, too, are they, and of clever criticism. Much of his correspondence with Sir Robert Ball will be preserved in the Library of Trinity College, Dublin. It largely refers to the Theory of Screws.

It is beyond my powers to convey the impression which Charles Joly made upon me. His books and papers speak for his rare gifts; and his best and most esteemed friend—among many friends—adds to this short notice an estimate of his mathematical work.

The circumstances of Joly's early death are indescribably sad. He was literally only beginning when life closed for him. A future excelling all his past was assured to him had the toil of youth but met its just reward and the harvest of life been his. The happy domestic life, the rare and precious gifts—honours of life so meekly borne—the whole bright future, all to be laid aside!

When he knew he was attacked by the dangerous illness which ended all, he wrote to a friend: "If the attack is as severe as Jessie's (his little daughter), I know quite well I cannot hold out. For myself I am content, though I should have given much to save the pain that others may feel. I confess also that I should like to be allowed to finish my life's work. Many unsolved problems might have some light thrown upon them if I had a little more time. I might have a useful influence in the affairs of College. I feel it would be a pity"—.

At the time of his death his hands were full of work. He had undertaken the article on "Quaternions" in the new edition of the 'Encyclopædia Britannica,' and had already entered upon the formidable duties of editing the whole of the articles on "Optics" for the same work. An unfinished Elementary Astronomy, having many features of novelty of development, remains behind, as well as a nearly finished Treatise on Solid Geometry. The latter promises to rank among his best writings.

Joly was, at the date of his death, Secretary of the Royal Irish Academy, Trustee of the National Library of Ireland, Member of Council of the Royal Dublin Society, and President of the International Association for Promoting the Study of Quaternions and Allied Systems of Mathematics.

J. J.

Professor Joly's paper on the "Theory of Linear Vector Functions" (1895), T.R.I.A., vol. 30, p. 597, was the commencement of a remarkable series of Memoirs on Quaternions, which has largely extended the applications of Hamilton's splendid invention. At the close of this paper he gives for the first time the relation between the theory of linear vector functions and the theory of screws.

In 1899 the first volume of the Second Edition of "Hamilton's Elements of Quaternions" appeared under the Editorship of Joly, and in 1901 this was followed by the second volume. The important work thus done in rendering Hamilton's masterpiece accessible has been greatly enhanced by the numerous notes and copious appendices which Joly has himself supplied. Attention may also be given to the significant words in the Preface in which Joly says: "My task as Editor has convinced me of the extreme caution with which any endeavour should be made to improve or modify the calculus of Quaternions." Joly, following to some extent the example of Tait, has made very extensive use of the linear vector functions. This beautiful part of the theory is shown to be admirably adapted to many different classes of physical investigation. In a remarkable appendix, Joly also shows how Quaternions provide the most natural method of investigating

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the systems of rays, which formed the subject of a famous Memoir of Hamilton in his early days and long before the Quaternions were thought of. Perhaps the part of the appendix which will be most generally appreciated is that on the operator Δ, of which many applications to hydrodynamical and other problems are given.

On the conclusion of this great work Joly turned his attention to the further development of Quaternions by continuing his original Memoirs. Such was his industry and so fertile was the method of Quaternions in his hands that in 1902 three important Memoirs appeared. The first contained an entirely novel development in which a Quaternion is represented as a point symbol. The point is supposed to have a weight equal to the Scalar of the Quaternion, while the vector of the point from a fixed origin is the quotient of the vector of the Quaternion by the Scalar. This was followed by another Memoir in which screws were represented as weighted points, and also by another on Quaternion arrays.

The year 1903 was one of still greater activity. An important paper appeared in the 'Phil. Trans.' (vol. 201, pp. 223—327) on "Quaternions and Projective Geometry." In this is developed the theory of the linear Quaternion function depending upon a latent biquadratic as the linear vector function depends on a latent cubic. The investigation exhibits the relation of Quaternions to Projective Geometry in quite a new light. Another Memoir in this year is on the Quadratic Screw System, in which a very large theory is most ably set forth. It was followed by a shorter Memoir on the Geometry of a New System of Screws. Here, again, the theory of linear vector functions is employed with much effect to set forth geometrical problems.

But, doubtless, the most important work in Quaternions with which the name of Joly will be remembered is his "Manual of Quaternions" which appeared in 1905. In this volume he follows at the outset a slightly different procedure from that adopted by Hamilton. Joly makes the result of the product of two vectors a matter of definition. There seems to be much gain from the point of view of the student in this modification. But the student, while he appreciates the facilities thus given at the beginning of his acquaintance with a new subject, will, as he advances, find it advantageous to turn to Hamilton and read his beautiful reasonings on the interpretation to be given to a product of two vectors.

By the excursions which Joly takes into various departments of Mathematical Physics such as the theory of Strain, Spherical Harmonics, Hydrodynamics and Electro-magnetism, the student of the Manual of Quarternions is introduced to regions far beyond those discussed by Hamilton, though not perhaps beyond those to which he foresaw his calculus might be extended. Indeed, the present state of Quaternions, to the advancement of which Joly has so largely contributed, goes far to justify the aspirations of Hamilton himself. Writing fifty years ago to Humphrey Lloyd, afterwards Provost of Trinity College, Dublin, Hamilton, says :—

"In general, although in one sense I hope that I am actually growing modest about the Quaternions, from my seeing so many peeps and vistas into future expansions of their principles, I still must assert that this discovery appears to me to be as important for the middle of the nineteenth century as the discovery of fluxions was for the close of the seventeenth."

R. S. B.

NOTE.

Obituary Notices of the following deceased Fellows are in preparation for press, to appear in the B Series of the 'Proceedings':—

Sir John Burdon Sanderson, Bart.
Henry B. Medlicott.
William T. Blanford.
Professor Thomas G. B. Howes.
Baron Ferdinand von Richthofen.
Captain Frederick W. Hutton.
George B. Buckton.
Charles B. Clarke.
Dr. Lionel Beale.
Rev. Canon Tristram.

J. Williams

(about 1875).

ALEXANDER WILLIAM WILLIAMSON.